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Economic and Administrative Feasibility Analysis of Alternative New-Car NOx Emission Charge Strategies

Policy Planning and Evaluation, Inc, McLean, VA

Prepared for

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CONTRACT #68-01-5124

prepared for

Economic Analysis Division
U.S. Environmental Protection Agency
Washington, D.C.

by

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1. EXECUTIVE SUMMARY

A. OBJECTIVE

This report examines the economic and administrative feasibility of using a charge, based on the level of emissions of oxides of nitrogen (NOx) from new automobiles, as a method of controlling the NOx emissions from new automobiles. The charge is considered only for NOx emission levels of 1.0 grams/mile (1.0 NOx) and below.* It is assumed that the statutory emissions standards (0.41 gram/mile for hydrocarbons (HC), 3.4 grams/mile for carbon monoxide (CO), and 1.0 grams/mile for NOx) mandated to come into effect in 1981 by the Clean Air Act will be in effect during any time for which the NOx charge is contemplated. Thus the sale of automobiles with emissions greater than 1.0 NOx will be prohibited by the standard. Special attention in this report is paid to reducing NOx emissions to the "research goal" of 0.4 NOx contained in the Clean Air Act.

B. COMPONENTS OF A NOx CHARGE

The components that make up a complete charge program are discussed in Chapter VI. These components and any conclusions reached are listed below.

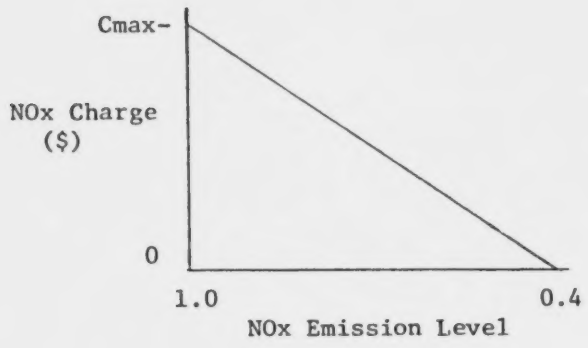
Type of Charge Schedule

The three types of schedules (sliding scale, on-off, and stepped) considered are shown in Figure I-1. Each schedule has advantages and limitations. The sliding scale schedule is the most reasonable from an

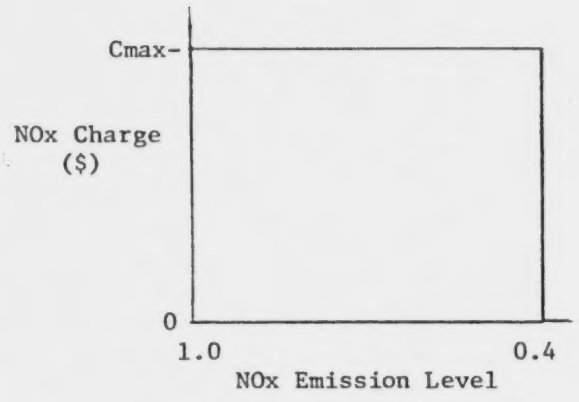
---

* Levels of emissions from automobiles are reported in grams of a particular pollutant emitted per mile of vehicle travel as measured in a standardized test procedure. Grams per mile is frequently abbreviated as "gpm".

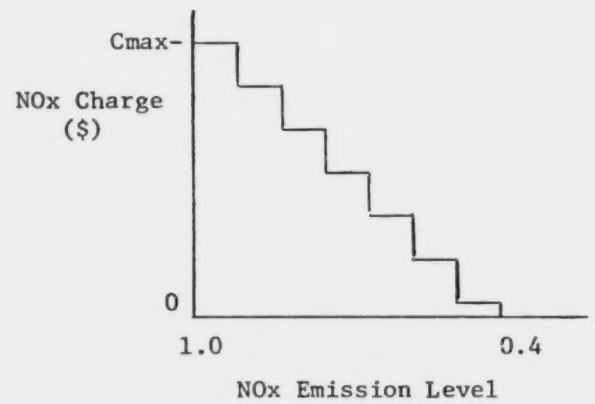
FIGURE I-1: TYPES OF CHARGE SCHEDULES CONSIDERED



SLIDING CHARGE SCHEDULE



ON-OFF CHARGE SCHEDULE



STEPPED CHARGE SCHEDULE

economic theory point of view while the on-off schedule would be the most effective in reducing all emissions to 0.4 NOx.

Rebates or Credits for Low NOx Emissions

Rebates (cash payments from the Federal government to the manufacturers of cars with low NOx emissions) and/or intercompany credits (the sale of credits, applicable only against the NOx charge, from manufacturers of cars with low NOx emissions to the manufacturers of cars with high NOx emissions) could raise several potential problems. These problems involve balance of payments concerns (possibility of cash payments to foreign manufacturers) and anticompetitive concerns (possibility of cash payments from "unhealthy" to "healthy" manufacturers). Intracompany credits which can only be applied against NOx charges owed are a reasonable option.

Phase the Charge in Over Time

The charge can be phased in by adjusting the amount of the charge and/or the NOx level at which the charge applies over time. This is a reasonable option providing the initial charge is sufficient to solicit some substantive reduction in emissions.

Testing Program and Emissions Measurement

Although the current EPA Certification Program is administratively the most attractive to use in determining the NOx emission levels on which to base the charge, there are unanswered questions (see below) as to its suitability for this purpose. Production line testing would require a major increase in the number of tests currently performed under the Selective Enforcement Auditing (SEA) program. (In-use testing was specifically excluded from the scope of this report.)

The question of the "emission measurement" on which to base the charge concerns whether to use emissions measured after the accumulation of some specified number of miles (e.g., 4,000 or 50,000 miles) or to use the total emissions between 4,000 and 50,000 miles as the basis for the charge. The emission level measured after the accumulation of 50,000 miles seems the most preferable basis, taking into account both theoretical and practical factors.

Charge Based on Emissions of Each Automobile or on Manufacturers' Sales Weighted Average Emissions

Basing the charge on the emissions of each automobile or on the sales weighted average emissions of a manufacturer are both reasonable alternatives. The final determination will depend on the type of charge schedule, the accuracy of the emissions measurement program, and the goal of the charge program.

Level of Charge

The major determinant in setting the level of the charge is the expected cost of controlling NOx emissions. The charge must exceed these costs to elicit any real response to the charge. Detailed information on the distribution of costs for different vehicles is needed to make estimates of the impact on emissions of any specific charge level. We have not been able to obtain these detailed cost estimates, due to the proprietary nature of the data. However, some indication of the appropriate level of charge is given by the estimated range of costs of reducing NOx emissions from 1.0 to 0.4 (between 0 and $180 per vehicle). Given that over 11 million automobiles were sold in the U.S. in 1978, any charge set at all but the lowest end of this range could represent a substantial amount of money unless a substantial number of automobiles have sufficiently low NOx emissions to avoid the charge.

C. FACTORS AFFECTING THE FEASIBILITY OF A NOx CHARGE

In designing and evaluating a NOx charge program, there are two major areas of concern:

- The economic and environmental impacts of the program and
- The administrative feasibility of the program

The first area basically involves answering the question, "If a certain NOx charge program is instituted, what will be the economic impacts on the economy as a whole and on various subgroups, such as auto manufacturers and consumers, and what will be the effect on NOx emission levels?" The second area involves answering the question, "Can the program be administered equitably and efficiently with a reasonable application of resources?" There are uncertainties with respect to the information needed to answer both these questions.

1. Uncertainties Affecting the Prediction of the Impacts of a NOx Charge

Uncertainties in 1) the costs of controlling NOx emissions to various levels on a firm-by-firm basis and 2) the likely responses of manufacturers to a NOx charge pose major difficulties in predicting the impact of a NOx charge. However, to the extent that the Ford Econometric Model* is representative of current industry conditions, it would appear that, on an overall industry basis, the sales impacts of a NOx charge program should be minimal.

*The model relates changes in new automobile sales to changes in automobile characteristics, including purchase price.

a. Effects of Uncertainties in the Cost of Emission Controls

The first step in evaluating the impact on emissions of a NOx charge is to estimate schedules of costs vs emission levels which manufacturers face as a result of the charge. Using these estimates, the financial incentives to reduce emission can be estimated. To obtain an estimate of both the number of vehicles for which there will be a financial incentive to reduce emissions, and the magnitude of these incentives at various emission levels, detailed estimates of the cost of controlling NOx emissions to various levels for various vehicles are needed. An estimate of the average cost of controlling an "average" vehicle is not sufficient since controls are installed on specific vehicles not on average vehicles. Average costs can only be used to get a general idea of the range of charge levels which may be needed.

Since such detailed estimates of the cost of controlling emissions were not available, the extent of the financial incentives to reduce emissions under a charge program could not be reliably estimated.

b. Effects of Uncertainties in Manufacturers' Reponses to a Charge

Under a NOx charge program, manufacturers are free to produce vehicles with up to 1.0 gpm NOx emissions, pay the required NOx charge, and concentrate their resources on improving features of their products that are not related to exhaust emissions. The extent to which this occurs will depend on the market for particular vehicles of the various manufacturers and on the dollar amounts of financial incentives resulting from the NOx charge.

2. Uncertainties Affecting Administrative Feasibility

The major issue with respect to the administrative feasibility of a NOx charge involves the measurement of the NOx emission levels on which the charge is based. There are unanswered questions as to the accuracy and

degree of variability of emission measurements on a single vehicle and also as to how representative the emissions of one test vehicle are of the emissions of other, untested, "identical" vehicles.

Another important question involves the number of models and various configurations of those models that will need to be tested under a NOx charge program. For example, if certification test results are used as a basis for the charge, the number of models and configurations tested may have to be increased depending on the specific requirements of the charge program. Any increase in testing or other change in current testing programs will influence whether or not a charge program is administratively feasible.

D. SPECIFIC CHARGE PROGRAMS

In Chapter VIII we present two specific charge programs. Program A uses a sliding scale schedule and Program B uses an on-off schedule combined with a sliding scale schedule. Given the uncertainties described above, these specific programs should be viewed as illustrative examples rather than definite proposals.

E. GENERAL CONCLUSIONS

Administrative Feasibility. Uncertainties related to emissions testing, especially the variability of test results and the related issue of what testing program would be needed to support a NOx charge program, raise significant, unanswered questions as to the administrative feasibility of a NOx charge. These questions would have to be answered before implementing a charge program.

Impact on NOx Emissions. Reliable estimates of the substantive response to a NOx charge could not be made with the information available. In other words, the reduction in NOx emissions "bought" by a charge program could not be reliably estimated.

II. INTRODUCTION

A. PURPOSE OF THE STUDY

This study examines the economic and administrative feasibility of establishing a program that relies on economic incentives as opposed to regulatory standards to control the emissions of oxides of nitrogen (NOx) from new automobiles. The specific economic incentive explored is a charge based on the NOx emission levels of new automobiles.* The purpose of such a charge program is to make it economically attractive for manufacturers to produce automobiles which have low levels of NOx emissions.

The major reason for considering a charge program as opposed to a regulatory standard is the flexibility that is introduced by a charge program. The emission control problem and the costs of controlling emissions can differ between manufacturers. Even the same manufacturer faces different situations with regard to the different types and sizes of cars in his product lines. Each manufacturer can respond to an economic incentive plan in the manner that minimizes his particular costs. Efforts can be concentrated where the greatest reduction in emissions can be most cheaply and easily achieved. A charge program can also lead to a diversity in control equipment developments. A rigid standard on the other hand, may tend to encourage all manufacturers to rely on a single technology that has the most certain prospect of meeting emission standards but which, in the longer run, may not be the most cost-effective technology to use for all models.

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* Many of the issues related to a NOx charge were originally discussed in a memorandum from Paul Stolpman, EPA Office of Policy Analysis, to the Assistant Administrator for Air and Waste Management (August 21, 1975).

One disadvantage of a charge system is that the amount of pollution reduction that will be attained is uncertain. Some manufacturers may elect to pay the charge and make no changes in their vehicles. A regulatory standard, on the other hand, has definite emission levels which must be achieved.

In designing and evaluating a NOx charge program there are two major areas of concern:

- the economic and environmental impacts of the program, and
- the administrative feasibility of the program.

The first area basically involves answering the questions, "If a certain NOx charge program is instituted, what will be the economic impacts on the economy as a whole and on various subgroups, such as auto manufacturers and consumers, and what will be the effect on NOx emission levels?" The second area involves answering the question, "Can the program be administered equitably and efficiently with a reasonable application of resources?" This report focuses on the aspects of a NOx charge which have a significant impact as far as the answers to these questions are concerned.

Throughout the report we have emphasized the practical implications of the various proposed programs. In dealing with complex matters such as automobile emission control, a reasonable, practical approach is perhaps all that can currently be conceived. A program designed solely on the basis of economic theory, where marginal costs are set equal to marginal benefits, cannot be implemented unless both the costs and benefits can be objectively quantified.

An illustration of one of the practical problems which will be more fully discussed in later chapters is the problem of making reliable measurements on which to base any NOx emission charge. A charge system under

which the amount of charge owed varied significantly solely due to the variability of emissions tests and not due to actual differences in emissions, could be challenged as being arbitrary. The reliability of the test procedure, thus, becomes an important design and evaluation criterion for any NOx charge program. The other "practical" considerations we have identified will be discussed in later chapters.

In the remainder of the Chapter we present some information on three topics which is helpful in placing the concept of a NOx charge in perspective. These topics are:

- the NOx problem in general,
- automobile exhaust emission standards, and
- automobile sales statistics.

B. THE NOx PROBLEM

In this section we present a very brief overview of the NOx pollution problem as it relates to automobiles.

1. Formation of NOx and Related Pollutants*

In automobiles, oxides of nitrogen, primarily nitric oxide (NO), are formed at high temperatures during the combustion process. NO reacts readily with the oxygen in the air to form nitrogen dioxide (NO_2). Both NO and NO_2 have adverse effects on human health, with NO_2 being the more harmful.

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* A complete description of the mechanisms of the formation and adverse effects of NOx related pollutants is found in reference 1.

Numbers raised above the lines of text refer to references listed in Appendix A, at the end of this report.

The formation of NO_2 is not the end of the NOx pollution problem. Some NO_2 in the presence of sunlight reacts with airborne hydrocarbons (HC) to form a complex array of chemical compounds which have collectively come to be known as photochemical "smog". Since even the mechanisms of pollution formation as a result of NOx emissions are very complicated, it is very difficult to assess the magnitude of the adverse effects that are attributable to NOx itself and to any one source of NOx.

2. Contribution of Automobiles to Total NOx Emissions

To gain some perspective on the contribution of the automobile to the overall NOx emissions problem, a few statistics will be helpful. Table II-1 gives estimates of the percentage of manmade NOx emissions contributed by all transportation sources (including automobiles) and by automobiles. Data for Los Angeles and the Washington, D. C. area are included only as illustrations of areas where the automobile contributes a substantially greater percentage of NOx emissions than is the case for the national average.

Figures on the total contribution of automobiles to NOx emissions do not fully reflect the significance of automobile NOx emissions to NOx related pollution problems. During commuting hours in urban areas, automobile NOx emissions are concentrated in both time and space and can give rise to high temporary concentrations of NOx-related pollutants.[1,3] The adverse effects of high short-term exposures as compared to the lower yearly average exposure are currently being assessed by EPA in its study of the need for a short term NOx standard. If it is found that a short-term NOx standard is required, this would probably increase the need for stricter automobile NOx control.

TABLE II-1. CONTRIBUTION OF ALL TRANSPORTATION SOURCES AND AUTOMOBILES TO TOTAL NOx EMISSIONS (1975)

Area	Percentage of Area's NOx Emissions Due to All Transportation Sources*	Percentage of Area's NOx Emissions Due to Automobiles
ENTIRE U.S.	46%	26%
Los Angeles	57%	35%
Washington, D. C. Metropolitan Area	63%	40%

* Includes automobiles.

Source: Reference 2.

C. AUTOMOBILE EXHAUST EMISSION STANDARDS

The measures taken by the Federal government to deal with air pollution from new automobiles primarily involve setting and enforcing specific exhaust emission standards which cannot be exceeded. The currently regulated components of exhaust emission for automobiles include: hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NOx). These standards are written in terms of grams of each pollutant emitted per mile (gpm) of vehicle travel. The shorthand method generally used to denote particular emission levels is to list the levels for each pollutant in the following order and format: HC/CO/NOx (e.g., .41/3.4/1.0 indicates emission levels for HC, CO, and NOx of .41, 3.4, and 1.0 gpm, respectively).

The exhaust emissions standards for 1981and later model year light duty vehicles (LDV), which include automobiles, are .41/3.4/1.0* In addition, EPA has proposed standards limiting the exhaust emissions of particulates from diesel powered automobiles.† (See Table II-2 for a more complete presentation of the current standards and those established for future model years.) Evaporative emissions from automobiles are also regulated but will not be discussed in this report.

The exhaust emission standards were mandated by Congress in the Clean Air Act Amendments of 1977 (PL 95-95). During the consideration of these amendments the level at which to set the NOx standard was a topic of some controversy. The 1981 model year NOx standard was finally set at 1.0 NOx, but, as part of the compromise, a "research objective" of 0.4 NOx was maintained (Sec. 202b7, Clean Air Act). The Administrator of EPA is required by Sec. 202a of the Clean Air Act Amendments of 1977 to study and report to Congress by July 1, 1980, the "health implications" and

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* Exhaust emission standards are found in Title 40, Code of Federal Regulations, Part 86 (40 CFR86).

† Volume 44, Federal Register pp. 6650-6657 (44FR 6650-6657).

TABLE II-2. AUTOMOBILE EXHAUST EMISSION STANDARDS*

(Grams per mile)

Model Year	HC	CO	NOx
1978-79	1.50	15.0	2.0
1980	0.41	7.0	2.0
1981 & beyond	0.41	3.4†	1.0‡, §

*Proposed Particulate Standards. EPA has proposed standards for particulate emissions from diesel automobiles of 0.6 gpm for 1981 and 0.2 gpm for 1983.

†CO Waiver. CO can be waived to 7.0 by the EPA Administrator for any model line if the Administrator finds: public health does not require attainment; the waiver is in the public interest; that good faith efforts have been made to meet the standard; that control technology will not be available considering cost, drivability, and fuel economy; and the National Academy of Sciences concurs on the non-availability of technology.

‡NOx Waiver. NOx can be waived to 1.5 for four model years for diesels or innovative technology if the Administrator finds there will be: no damage to public health; significant fuel savings; potential for long term air quality benefits; and potential to exceed fuel economy standards.

§NOx Research Goal - 0.4 NOx. The law keeps 0.4 NOx as a research goal. EPA is to report to Congress by July 1, 1980, on the need for a 0.4 NOx standard to protect health and on the cost and technology capable of meeting 0.4 NOx.

the "cost and technological capability" of meeting a 0.4 NOx standard.

In our present study we assume the 1981 standards prohibiting the sale of automobiles with NOx emission levels above 1.0 gpm will come into effect on schedule. Consequently, any charge programs we consider apply only at or below 1.0 NOx. Special attention is paid to reducing NOx emissions to the "research goal" of 0.4.

The appropriate levels at which to set the various exhaust emissions standards have been the subject of continuing controversy. This is due largely to the difficulty of objectively quantifying the costs vs. the benefits of any particular standard. Much of the discussion has been forced to center more on what emission levels are technically feasible to achieve at some reasonable increase in equipment cost. Even at this level the arguments are imprecise because the availability of new pollution control technology must be predicted. Thus, waiver provisions have been incorporated into the statutory requirements due to uncertainty over the effects of exhaust emissions and the capabilities of emission control devices.

D. AUTOMOBILE SALES STATISTICS

The number of vehicles sold in the U.S. during 1978 is given in Table II-3. From the point of view of obtaining a perspective on the possible overall magnitude of the amount of money that could be involved in a NOx charge program, the most important number in the Table is the total sales--over 11 million automobiles.

E. SCOPE OF THIS STUDY

In this section we list the limitations to the scope of this study and present an outline of the organization of the study.

TABLE II-3. AUTOMOBILE SALES IN THE US

(January-December 1978)

Manufacturer[1]	Sales (Thousands of automobiles)	Sales as Percent of Total U.S. Sales (%)	Sales as Percent of Total Sales of U.S. Produced Automobiles (%)
GM	5,385	47.60	57.86
Ford	2,583	22.83	27.75
Chrysler	1,146	10.13	12.32
AMC	171	1.51	1.83
VW of America[2]	23	.20	.24
Total Domestic	9,308	82.27	100
Imports	2,005	17.73	
Total	11,313	100	

[1]Sales by U.S. manufacturers of automobiles produced outside the U.S. (Canada excepted) are treated as Imports.

[2]Volkswagen of America started producing "Rabbits" in U.S. in 1978 - 5 months data.

Source: Automotive News 1979 Market Data Book

1. Limitations to the Study

Specific limitations and assumptions are given in the following list:

- The effects on air quality due to the reduction of NOx emissions from new automobiles are not specifically estimated.
- The environmental damage due to NOx emissions from automobiles is not assessed.
- The charge programs considered include only new automobiles.
- All charge programs considered use pre-sale emission testing as a basis for the charge. In-use testing programs are specifically excluded.
- Charges are considered only for NOx emissions levels of 1.0 gpm and below. It is assumed the 1981 regulatory NOx standard of 1.0 will be in effect.

2. Organization of the Study

The remainder of this report is organized as follows:

- Chapter III - Emission Control Technologies. This Chapter describes the currently used and proposed future technologies for controlling automobile exhaust emissions. The standard gasoline engine, the diesel engine, and various new engine types are discussed. Some estimates of the costs of controlling NOx emissions to various levels are included.
- Chapter IV - Testing Procedures for Determining Emissions Levels. This Chapter describes the current emission testing programs that are used to enforce the regulatory standards. The accuracy of these tests is explored, and the implications that the degree of testing accuracy has to implementing a charge program is examined.
- Chapter V - Predicting the Responses of Consumers and Manufacturers to a NOx Charge. The response to a NOx charge in terms of actual changes in automobiles offered for sale by manufacturers and purchased by consumers is examined.
- Chapter VI - Defining the Components of a NOx Charge Program. This Chapter discusses the components that are involved in designing a NOx charge program. The merits of the various alternatives with respect to each component are discussed.

- Chapter VII - Unknowns in Developing a Charge Program. The effects of a lack of information regarding the cost of controlling emissions and the accuracy of emissions measurements are discussed.
- Chapter VIII - Proposals of Specific NOx Charge Programs. This Chapter describes several complete alternative charge programs.
- Chapter IX - Conclusion.

III. DESCRIPTION OF EMISSION CONTROL TECHNOLOGIES

A. INTRODUCTION

This chapter is intended to serve as an introduction to emission control technologies. The technologies that are currently most widely used or most likely to be introduced in the future are briefly described. The discussion is divided into a section covering the control of emissions from the conventional spark ignition engine and a section covering other types of engines. Information on the cost of controlling emissions to various levels is also presented.

As an aid in placing the emissions control problem in perspective, we present 1) a brief history of the development of the automobile and 2) a description of how pollutants (HC, CO, and NO_x) are formed in an automobile and an explanation of the general approaches to reducing the emission of these pollutants.

1. Historical Developments Affecting the Automobile

The conventional gasoline engine was developed over a period of time during which exhaust emissions were of little or no concern, and during which gasoline was plentiful and relatively inexpensive. Consequently, the major design considerations were low cost, reliability, and good performance. When exhaust emission control became a requirement, the response of manufacturers was to leave the basic engine design unchanged and to control emissions by readjusting the engine and/or adding on equipment that reduced emissions. This still remains the basic strategy for controlling emissions from most present day automobiles.

With the advent of the "energy crisis," fuel economy was added to the list of primary design criteria. This was brought about by consumers' preference for fuel efficient automobiles and by Federal

fuel economy regulatory standards.[4] The goal of increased fuel economy has led to significant, on-going, changes in automobiles with the major emphasis on weight reduction and consequent "down-sizing."

The desire for lowered exhaust emissions and/or improved fuel economy has also increased interest in engines other than the conventional gasoline engine for use in automobiles. These include engines such as the diesel and stratified charge engines, which are available on some models now, and others, such as the gas turbine and sterling engines, which are in the research and development stages.

A brief description of these engines and of automobile exhaust emission control devices is given below. Before moving to this topic, we include a brief overview of the causes of the formation of HC, CO and NOx and what general strategies are used to reduce the level of their emissions.

2. Automobile Emissions - Sources and Control Approaches*

HC and CO are formed as a result of incomplete combustion of the fuel. Methods to control these pollutants involve attempts to assure the complete combustion of the fuel to harmless products, water and carbon dioxide (H_2O and CO_2). This can be accomplished by either assuring complete combustion in the original combustion process in the combustion chamber, or by completing combustion somewhere in the exhaust system after the exhaust leaves the engine.

NOx is formed at high temperature during the combustion process by the combination of oxygen (O_2) and nitrogen (N_2). The N_2 and O_2 do not arise from the fuel itself, but are supplied from the air in the air-fuel combustion mixture. As with HC and CO, the NOx problem can be

*For a more complete discussion see reference 5.

attacked by either preventing NOx formation during combustion or by removing NOx from the exhaust gasses. NOx is "removed" from the exhaust gas by causing it to dissociate to O_2 and N_2.

As the above discussion illustrates, the origin of HC and CO is quite different from that of NOx. This can necessitate different control strategies for the two groups of pollutants which makes the simultaneous control of all three pollutants much more difficult than the control of each individually. For example, in some instances, a strategy that works well to control one pollutant will actually cause an increase in the emission of another pollutant.

Control of exhaust pollutants can be accomplished by making changes in three general areas: 1) Control of the fuel mixture prior to combustion; 2) Modification of the combustion process itself; and 3) treatment of the exhaust gases after combustion. The overall level of pollution control depends on the modifications made in each of these areas and how these modifications compliment each other. For example, a new exhaust treatment system may require changes in the fuel mixture or combustion process so that the proper mixture of exhaust gases is delivered to the exhaust treatment system.

B. CONTROL TECHNOLOGIES FOR CONVENTIONAL SPARK IGNITION ENGINES*

The following is a brief description of some of the emission control techniques and technologies applicable to the conventional spark ignition engine. This is not a complete discussion of exhaust emission control technologies, but merely a summary of techniques that are now or are expected to be the most widely used. Many of the techniques listed here for the standard spark ignition gasoline engine are also applicable

*See references 5 and 6 for an expanded description of control equipment.

to the other engine types discussed below in Section C.

1. Fuel Mixture Control

Exhaust emissions can be reduced by assuring the proper air/fuel mixture is present in the combustion chamber under various operating conditions. In addition, NOx emissions can be reduced by mixing inert gases with the combustion mixture.

a. Improved Carburetors and Fuel Injection

Improved control of the air/fuel mixture can be accomplished by using improved carburetors or some type of fuel injection. Additional control can be provided by using a feedback system (discussed below) to control the carburetor or fuel injection system.

b. Feedback System - Oxygen Sensor

Some exhaust treatment systems, especially the three-way catalyst system described below, require precise control of the composition of the combustion products from the engine for proper operation. This is accomplished by installing an "oxygen sensor" in the exhaust system. The sensor makes measurements on the exhaust gas composition and sends an electronic signal to the carburetor or fuel injection system where adjustments of the air/fuel ratio are made. (Only the thermodynamic oxygen potential is measured. A complete analysis of the exhaust gas composition cannot be made by the sensor.) This system has the advantage that it is essentially self correcting and reacts to actual in-use operating conditions. The feedback system combined with either the carburetor or fuel injection system it controls is referred to as the "Fuel Metering System".

c. Exhaust Gas Recirculation (EGR)

Exhaust gas recirculation (EGR) is a technique used to reduce NOx formation during the combustion process. EGR works by recirculating a portion of the exhaust gases back into the combustion chamber. These gases are inert as far as further combustion is concerned, and the effect is to lower the peak combustion temperature, thereby discouraging NOx formation. The amount of exhaust gases recirculated can be varied to achieve different levels of NOx control. However, past a certain point, fuel economy is inversely proportional to the amount of EGR used.

2. Modification of the Combustion Process

Major changes to the combustion process involving substantial changes to the geometry of the combustion chamber are discussed in the section below on "Other Engines." Minor adjustments that can be made include changes in: spark timing, compression ratio, and ignition system. Changes in the spark timing and the compression ratio made to reduce emissions generally have adverse effects on fuel economy and/or performance. Improvements in the ignition system have positive effects in all areas, but add to the cost of the automobile.

3. Exhaust Treatment

Exhaust treatment technologies are used to eliminate pollutants from the exhaust gases after they leave the combustion chamber. Various treatment technologies are described below.

a. Thermal Reactor

Thermal reactors are used to promote the oxidation of HC and CO by providing a high temperature environment where excess oxygen is present. The reactor is generally located near the engine due to the need to

attain high temperature.

b. Air Injection

Air injection can be used in conjunction with a thermal reactor or other control device which requires excess oxygen to be supplied from the atmosphere. A mechanical air pump run by the engine supplies air to the desired location.

c. Catalyst Technology

A catalyst is a substance which, without being consumed in a chemical reaction, speeds up the rate of that reaction. The reaction occurs on the surface of the catalyst where the reactants are adsorbed, react, then leave the surface of the catalyst. Since the reaction occurs only at the surface of the catalyst, the important parameter is the surface area of the catalyst material. Most exhaust treatment catalysts are noble metals, such as platinum (Pt), rhodium (Rh), and paladium (Pd), which are relatively expensive materials. However, since only the surface area of the catalyst material is important, the noble metals can be used in the form of very thin coatings covering some less expensive, inert, support material. Consequently, the weight of the active catalyst material needed can be kept to a minimum.

A typical catalytic converter consists of an inert support, such as alumina pellets or honeycomb, covered by a thin layer of active material. The coated pellets or honeycomb are contained in a stainless steel housing. This assembly is mounted in the exhaust system, where its appearance is similar to that of an additional muffler. Catalytic converters can be mounted further from the engine than thermal reactors since catalysts can operate at lower temperatures than thermal reactors. Current catalysts are poisoned (become inactive) by small amounts of lead, phosphorous, and sulfur and thus require the use of fuels containing

low levels of these substances.

There are two major categories of catalytic converters: oxidation and reduction. Some systems use two catalytic converters in series or even combined in one housing. As development of advanced designs has proceeded, the difference between some of the designations has become blurred. The function of the two basic catalytic converter types and several of the commonly used combinations is given below.

i. Oxidation Catalysts

Oxidation catalysts (OC) are used to promote the oxidation of HC and CO to H_2O and CO_2. Air-injection can be used in conjunction with oxidation catalysts.

ii. Reduction Catalysts

Reduction catalysts promote the dissociation of NOx to its constituents, O_2 and N_2.

iii. Three Way (3W) Catalysts

Three way (3W) catalysts accomplish the control of all three regulated pollutants, HC, CO and NOx, in a single converter. For proper operation, precise control of the exhaust gas composition reaching the catalyst must be maintained. This control is most likely to be obtained by using an oxygen sensor feed-back system.

iv. Three Way Plus Oxidation Catalysts (3W+OC)

Three way plus oxidation catalysts (3W+OC) employ a three way catalyst followed by an oxidation catalyst. Air is generally injected upstream of the oxidation catalyst.

v. Dual Catalysts

Dual Catalysts employ a reduction catalyst followed by an oxidation catalyst. Air is injected upstream of the oxidation catalyst.

vi. Start Catalyst

Special catalysts that come into operation rapidly, before the main catalyst system heats to its operating temperature are called "start catalysts". There are many possible configurations, but the main features are similar to the various catalysts described above. A start catalyst is generally smaller and located closer to the engine than the main catalyst.

The above is a brief outline of the major technologies and techniques that are used to control emissions from conventional spark ignition engines. There are many possible modifications to the systems and new developments and improvements can be expected as more experience in pollution control systems is gained.

4. Emission Control Costs - Conventional Spark Ignition Engine

In order to predict the level of emissions reduction that will result from instituting a particular NO_x charge program, fairly detailed estimates of the cost of controlling emissions to various levels are needed. Since the costs of controlling emissions will differ depending on the particular characteristics of various vehicles and on the control technologies employed, any specific level of NO_x charge may elicit different responses with respect to different vehicles. Specific estimates of the cost of controlling various types of vehicles to various emission levels are thus needed to evaluate the impact of a NO_x charge. It is also desirable to have estimates of how these costs may change over time.

We have not been able to obtain the types of detailed estimates referred to above. The major problems here are that a good deal of company-by-company data are proprietary. Also, the automobile itself is undergoing substantial changes and automobile emission control technologies are evolving. It is therefore difficult to estimate what technologies will be used in the future and what their costs and capabilities will be.

The most current estimates we have found of the most likely control technologies that will be employed to meet low NO_x levels and the cost of these technologies are contained in a paper by Karl Hellman and Robert Wagner.[7] We include these estimates in the following sections.

a. Most Likely Control Technologies*

The control systems that most likely will be chosen to achieve low NO_x emissions will use combinations of several of the technologies described in Sections 1 through 3 above. The systems will employ a catalyst system and a feedback system controlling either a carburetor or some type of fuel injection system (fuel metering system). Specific designations of the two possible catalyst system and the three possible fuel metering systems are given in Table III-1.

Six basic systems can be defined by various combinations of the catalyst and fuel metering systems. In addition to these components, most systems will employ exhaust gas recirculation (EGR) and some will use some sort of air injection. These are current estimates of the types of systems that will be employed. Of course, technological developments could change the situation.

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*The material in this section was taken from reference 7.

TABLE III-1

LIKELY EMISSION CONTROL SYSTEMS

Catalyst System	Fuel Metering System
3-Way Catalyst	Feedback system controlling carburetor
3-Way plus Oxidation Catalyst	Feedback system controlling fuel injection system (2 types of fuel injection possible)

b. Cost Estimates*

Since there are a variety of "likely" systems, and since the precise details of the systems that will be employed in the future to reach low NO_x levels are not known, there is a good deal of uncertainty as to the cost of achieving various NO_x levels. Consequently only a range of cost estimates can be made for the cost of emission controls at various levels. Using the "most likely control systems" described above in Section a. as a basis, cost ranges for meeting two NO_x levels, 1.0 and 0.4, have been estimated for an "average" car (See Table III-2).

*Estimates from reference 7. For a presentation of the costs of current control equipment see reference 8.

TABLE III-2

COSTS FOR EMISSION CONTROLS

(1978 Dollars)

Emission Standard (grams/mi)	Cost Range* Per Vehicle
.41 HC, 3.4 CO, 1.0 NO_x	$194 to 285
.41 HC, 3.4 CO, 0.4 NO_x	$236 to 377

*Costs are all relative to an uncontrolled car.

Source: Reference 7.

Since the cost ranges indicated in Table III-2 overlap, $0 can be taken as the minimum difference in cost of reducing NOx emissions from 1.0 to 0.4 grams/mile. The maximum difference in cost is ($377-$194) = $183.

The costs discussed thus far represent the cost of the control equipment itself. No estimates have been given of any increased or decreased costs of maintenance, changes in fuel economy, or impairments in drivability resulting from decreasing NOx emissions from 1.0 to 0.4 NOx. There is some question as to whether low NOx emission levels can be achieved without any adverse effects on these factors.* The charge can be structured to include or not include operating and maintenance (O + M) and fuel economy considerations. If, as EPA staff indicate, improvements in fuel economy and decreased maintenance costs are likely to result, the cost range of $0 to $183 is overstated.

*See references 9 and 10.

C. ENGINES OTHER THAN STANDARD SPARK IGNITION

This section contains a discussion of various types of engines other than the standard spark ignition engine. This is not intended to be a thorough presentation but merely an introduction to some of the engines which either are now or may be used in passenger cars.

1. Spark Ignition Stratified Charge Engines

In a stratified charge engine, the air/fuel mixture is not spread homogeneously throughout the combustion chamber, but is distributed into fuel-rich and fuel-lean regions. A spark plug ignites the fuel-rich mixture, which in turn ignites the fuel-lean mixture. These types of engines offer improvements in fuel economy and may offer some improvements in exhaust emissions.

There are many designs based on the stratified charge engine, with the most well-known the Honda CVCC (Compound Vortex-Controlled Combustion) engine which is available on some current models. Most other manufacturers, notably Ford, with its PROCO engine, are doing some R&D on stratified charge engines.

2. Diesel Engines

The diesel engine is essentially a stratified charge engine, where the fuel is ignited by compression rather than by a spark plug. Diesel engines have been in use for many years in heavy duty vehicles and are finding increased use in passenger cars.[11] The major reason for switching to diesels is their fuel economy. For comparable automobiles, diesels can provide at least a 25% improvement in fuel economy over a conventional gasoline engine.[4]

The major questions concerning increased use of diesels involve

exhaust emissions. The pollutants involved include particulate emissions, odor, and NOx. Whether diesels can meet a 1.0 or 0.4 NOx standard was debated during the hearings on the 1977 Clean Air Act Amendments. The compromise reached provided for granting temporary (4 year) waivers of the 1981, 1.0 NOx, standard to 1.5 NOx.

The major problem in controlling NOx emissions from diesels is that, due to the nature of the diesel exhaust, catalyst technology cannot be used in the control of NOx. EGR can be used down to approximately 1.0 NOx; however, there is a debate as to whether 0.4 NOx can be reached with acceptable deleterious effects. Computer calculations indicate that low emission diesels are feasible but many of the principles have yet to be demonstrated on actual working automobiles.

3. Rotary Engines

Rotary engines can incorporate as many modifications as the conventional reciprocating engine. Some work is underway to develop fuel efficient low emissions rotary engines, but it is unclear whether these goals can be met with an advantage over more conventional engines.

4. Other Developments in "Conventional" Engines

There are many ideas and development programs directed toward improving various aspects of spark ignition and diesel engines, which we will not attempt to discuss. A major development or a combination of minor improvements can lead to significant benefits in terms of all aspects of vehicle performance, fuel economy, emissions and/or initial cost. At this point, it is impossible to guess exactly what future technological developments and what systems will prove acceptable for general use by the driving public.

5. Future Engines

Entirely new types of engines that may provide significant advantages in all aspects of engine performance, fuel economy, and emission control are under development. Whether reliable models suitable for public use can be manufactured at acceptable costs is uncertain. Wide introduction of these engines would require extensive changes in the auto manufacturers' production facilities. A list describing the major categories is given below.

a. Gas Turbine

In a gas turbine engine, the fuel burns continuously. As the fuel mixture burns and expands, it is directed at a turbine, causing it to spin. Mechanical energy can then be extracted from the turbine.

b. Rankine and Sterling Cycle Engines

The Rankine and Sterling cycle engines are both external combustion engines. The heat from the continuously burning fuel is used to heat the engine's working fluid. In the Rankine cycle engine, a liquid working fluid is boiled to create a pressurized gas that is then converted to mechanical energy. (A steam engine is one type of a Rankine cycle engine.) In the Sterling engine, the pressurized gas is created by heating a gas phase fluid.

The advantage of these cycles, as far as exhaust emissions are concerned, comes from the fact that they are external combustion engines. The combustion process can be controlled independently of the internal working of the engine itself.

c. Electric Vehicles

Electric vehicles are under development and may come into use in the future. Emission problems related to HC, CO, and NOx are transferred from the automobile to the power plant.

IV. TESTING PROCEDURES FOR DETERMINING EXHAUST EMISSION LEVELS

The accuracy and validity of NOx emission measurements are of critical importance both in designing and evaluating the feasibility of a NOx charge program. A charge program in which the amount of charge owed varied significantly as a result of testing variability could be challenged as being arbitrary. A closely related issue involves the number and cost of any additional emissions tests (i.e., tests over and above those already performed in current programs) that are required to obtain sufficiently accurate data to support a NOx charge. In this chapter, we:

- outline the current FPA emission control programs and testing procedure used to enforce the exhaust emission standards for new automobiles,
- examine the costs of emission tests,
- look at the accuracy of the current testing programs and procedures, and
- examine the ramifications, if any, that a lack of accuracy and/or a need for improved accuracy have with respect to implementing a NOx charge program.

A. SUMMARY OF CURRENT EPA EMISSION CONTROL PROGRAMS FOR NEW AUTOMOBILES

The current programs can be separated into three distinct groups identified, respectively, with the development, mass production, and use of an automobile.

Certification: Prior to production, prototype vehicles, representing various engine families and models, must be tested to assure that the basic design is capable of meeting the applicable emission standards over the life of the automobile. On the basis of these tests, the Administrator of EPA determines whether the models represented can be certified and allowed to be offered for sale.

Selective Enforcement Auditing (SEA): The SEA program is used as a policing mechanism to try to ensure that the assembly line copies of certified vehicles conform to the exhaust emission standards. This is done by surprise (to the manufacturers) testing of samples drawn from the output of production lines.

Inspection/Maintenance: In-use or inspection/maintenance (I/M) programs* are designed to ensure that vehicles actually in use continue to conform to the emission standards. These programs are run by the states, and are required for HC, CO, or NOx nonattainment areas in the 1980's.

Since the scope of this report is limited expressly to exclude any in-use program as a basis for any NOx charge proposed, we will not include any further description of in-use programs. We would like to note, however, that any NOx charge program which uses pre-sale emission tests as a basis for a NOx charge on new automobiles does not preclude the implementation of a "follow-up" in-use charge program.

We now present an expanded summary of the certification and SEA programs and a description of the actual emission testing procedures. This is not intended to be a complete technical description but rather a description of how the system works and a discussion of any drawbacks to the system which have an impact on determining whether or not a NOx charge program is compatible with the current pre-sale emission testing programs.

B. CERTIFICATION

Under section 203 of the Clean Air Act, it is unlawful to offer for sale any new automobiles that do not conform to Federal exhaust emission regulations. Manufacturers must obtain a certificate of conformity for

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* For a description of I/M Programs, see reference 12.

each model they wish to produce in any model year from the EPA As part of the certification procedure, the manufacturers must submit to EPA extensive emission test data collected in accordance with EPA regulations. The manufacturers are also required to make the test vehicles available to the EPA, if requested, for retesting.

The regulations governing the certification process and emissions testing procedures are contained in Title 40, part 86, of the Code of Federal Regulations (40CFR86).

Many new or revised regulations are promulgated well in advance of the model year of their initial applicability. Thus, at any one time, the promulgated regulations applicable to the current and future model years may differ. The description of the certification procedures we present is based on the 1979 model year procedures, but points out any significant changes in the procedures that will take effect in future model years and that have been promulgated at the time of this writing. The certification regulations, fully described in 40CFR86 Subpart A, are summarized below.

1. Beginning the Certification Procedure

The manufacturer submits an application for certification to the Administrator of EPA (the Administrator). Among other items, this application must contain a:

- technical description of all vehicles, including a description of the engine and emission control system, for which certification is desired;
- forecast of U.S. sales for each model;
- statement of recommended maintenance;
- (for 1981 and later model years) information on all parameters that are physically capable of being adjusted; and
- description of the equipment and procedures the manufacturer will use to make the required emission tests.

2. Classifying and Selecting Vehicles for Testing

Once the preliminary application is approved by EPA, the next step is to select the vehicle fleets for emission testing.

a. Engine Families: The vehicles covered by the application are divided into "engine families." The engine families are comprised of vehicles, which by virtue of their engines and emission control equipment, are expected to have similar emission characteristics over their useful lives (50,000 miles*). Although the manufacturer can suggest the composition of engine families, the EPA has the ultimate authority to make the classification.

b. "Emission" and "Durability" Vehicles: Within each engine family, emission and durability data vehicles are selected. (The purpose of selecting these vehicles is explained below.)

i. Emission Data Vehicles: Within each engine family emission data vehicles are selected according to the following procedure:

1. Vehicles within an engine family are divided into engine displacement-exhaust emission control system combinations and a projected sales volume for each combination established. One vehicle of each combination is selected in order of decreasing projected sales volume until 70 percent of the projected sales volume of the engine family is represented or until a maximum of 4 vehicles is selected.
2. Four additional vehicles which are expected to have the highest emission levels of the vehicles in the engine family can be selected.
3. If the vehicles selected in 1 and 2 above do not represent each engine displacement-emission control system combination in the engine family, then one vehicle can be selected from each of the remaining combinations.

*Although most automobiles can be expected to "live" for at least twice 50,000 miles, the Clean Air Act (Sec. 202 (d)(1)), specifically defines the useful life of an automobile as "a period of use of five years or of fifty thousand miles (or the equivalent), whichever first occurs."

While this procedure assures that a vehicle from each engine displacement-exhaust emission control system combination is selected as an emission data vehicle, it by no means assures, or is intended to assure, that all vehicle configurations within the engine family are selected.

ii. Durability Data Vehicles: For each emission control system in the engine family, the EPA selects one durability vehicle. In most instances only one vehicle need be selected to represent the entire engine family, since the requirement that all vehicles in the engine family be expected to have similar emission characteristics over their useful lives generally, but not always, means that all vehicles in the engine family utilize the same type of emission control system.

3. Mileage Accumulation and Emission Measurement

a. Emission Vehicles: All emission vehicles are driven* on a test track to a total distance of 4,000 miles. Emission measurements are made before and after the accumulation of the 4,000 miles. The accumulation of 4,000 miles is done to determine the emissions of an essentially new, but "broken-in," car.

b. Durability Vehicles: All durability vehicles are driven* on a track to a total distance of 50,000 miles. Emission measurements are made before any mileage is accumulated and at 5,000 mile intervals thereafter. This procedure is followed to determine how the emissions of the vehicle change over its assumed useful life of 50,000 miles.

c. Emission Measurements: The manufacturer performs the required emission tests on emission and durability data vehicles using the

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*The procedure for accumulating the mileage is the "Durability Driving Schedule" specified in Appendix IV of 40CFR86.

appropriate test procedures and submits the results to EPA. At any point in the testing program, EPA may require any of the test vehicles be submitted for emission testing. (The testing may be conducted at the manufacturer's facility.) Prior to any emissions testing of 1981 and later model year vehicles, EPA may adjust or cause to be adjusted any parameter of an emission data vehicle that has been designated by EPA as "adjustable" in the review of the original certification application. The purpose of this new regulation is to assure that vehicles are designed so that they cannot be easily adjusted, while in use, to a condition in which they exceed the applicable emission standards. While the regulation will aid in decreasing in-use emissions, it may add to the variability of the actual emission values measured in pre-sale testing.

4. Determining Whether Emissions Standards are Met

Since the efficiency of emission control devices usually decreases (emissions increase) over the life of the vehicle, a vehicle's emissions after the accumulation of 50,000 miles are used as the basis for determining compliance with the standards. Since only one vehicle representing each emission control system in an engine family is actually driven to 50,000 miles, the emission results from the emission data vehicles, which are driven to only 4,000 miles, must be extrapolated to 50,000 miles. The results from the 50,000 miles durability vehicles are used to obtain the proper number to use in the extrapolation. The number by which the 4,000 mile emission results are multiplied to obtain the extrapolated 50,000 mile results is referred to as the "Deterioration Factor" (DF).

a. Deterioration Factor (DF): The deterioration factor is computed from the durability vehicles' emissions measurements in the following manner: (1) All the applicable durability emissions measurements,

excluding the zero mile emission measurements, are plotted as a function of mileage. (2) The best straight-line fit to these points, calculated by the method of least squares, is computed. (3) Using the least squares line, the emissions at 4,000 and 50,000 miles are interpolated and the ratio computed.

$$DF = \frac{\text{Emissions at 50,000 miles}}{\text{Emissions at 4,000 miles}}$$

(If the ratio is less than one, the DF is taken to be equal to one).

b. Emissions Data at 50,000 Miles: The 4,000 mile emissions of the emission data vehicles are extrapolated by

DF x (4,000 Mile Emissions of Emission Data Vehicle)

to give the 50,000 mile values which must be no greater than the emission standards. This procedure is carried out separately for each pollutant (HC, CO, and NOx) for each emission data vehicle in the engine family.

These certification tests are generally carried out on prototype vehicles prior to placing the various models in production. For many of the steps in the process, the Administrator has discretionary power to modify or waive some or all of the requirements. One important discretionary power permits the Administrator to allow a manufacturer to certify a new vehicle that is similar to a vehicle which has been certified in the past, without actually testing the new vehicle. This permits a manufacturer in some instances to "carry over" the emission test results from year to year on models that have not been substantially changed and, thus, can be judged by the Administrator to be "similar" to previously certified models.

5. Current Trends in the Certification Procedures - Abbreviated Certification

In the past EPA has opted to perform almost all the emissions tests related to certification itself. In an effort to streamline the procedure an Abbreviated Certification* procedure is being instituted. Under Abbreviated Certification EPA will not test all vehicles itself but will rely heavily on manufacturers' test results. The vehicles which will be allowed to be certified under this program will be carefully selected by EPA engineers on the basis of past experience and engineering evaluations to be expected to be able to pass the certification tests. Vehicles for which EPA has some reason to believe there will be a difficulty in passing the certification test will be tested by EPA. In this way EPA hopes to reduce the time and cost of certification by concentrating its efforts on potential "problem" vehicles.

The Abbreviated Certification procedure fits well with the pass/fail nature of the certification program. There is no reason for EPA to carefully check the emissions of vehicles which, by other means, can be judged to be fairly certain to comply with emission standards. However, if a change in the nature of the emission program necessitated that EPA determine the absolute level of emission rather than just whether the emissions are below a certain level, the Abbreviated Certification procedure might not be appropriate.

If the actual level of emissions of certification vehicles is needed for an emissions charge program, EPA may have to reconsider performing all the tests itself rather than using numbers supplied by the manufacturers. This would essentially reverse the current trend in the certification program.

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* The complete proposed rules for Abbreviated Certification and related changes in the Certification Procedure have not yet been published. An overview of the program is provided in reference 13.

6. Costs of Certification Tests

There are two types of tests which are performed in the certification program: 1) Durability data vehicle tests used to determine the deterioration factor (DF) and 2) Emission data vehicle tests. Estimates currently used by EPA of the costs of performing these tests are given in Table IV-1. The total cost is broken down into: the cost of the prototype vehicle tested, the cost of accumulating mileage, and the cost of the emission tests themselves.

TABLE IV-1. COST OF CERTIFICATION TESTS

Emission Data Vehicle Test

Prototype Vehicle	$ 12,600
Mileage Accumulation to 4,000	8,100
Two Emission Tests @ $375 per test	750
Total	$ 21,450

Durability Data Vehicle Tests (Determination of DF)

Prototype Vehicle	$ 31,500
Mileage Accumulation to 50,000	120,000
Fourteen Emission Tests @ $375 per test	5,250
Total	$156,750

Source: Reference 14, pp. 49, 51.

C. SUMMARY OF SELECTIVE ENFORCEMENT AUDITING (SEA) REGULATIONS

Once a model is certified, it can be placed in production and offered for sale. The SEA program (40CFR86 Subpart G) is used to police production by providing for unannounced emission tests to be conducted on samples of actual production vehicles. SEA operates as described below.

1. Test Order

The Administrator issues a "test order" to a manufacturer. The order specifies: the vehicle configuration, the plant or storage facility from which the vehicles to be tested will be selected, the number of vehicles (batch size) from which samples will be drawn, and whether the vehicles will be drawn randomly or sequentially from the batch. No advance notice need be given to a manufacturer before he must begin to comply with the order. In current practice a manufacturer may be notified a day in advance of an audit but will generally not be told which of his automobile models will be audited until an EPA audit team arrives at the manufacturing plant with the test order. Selection of automobiles for testing may commence immediately. The selection of the automobiles is supervised by EPA.

During a model year, the Administrator may not issue more than one test order to a manufacturer, per 300,000 projected sales volume for that manufacturer. In some instances, this limit can be increased as a result of failures of an audit or when evidence exists to indicate possible noncompliance of certain production vehicles. A total of approximately 40 audits are conducted by EPA each year.

2. Vehicle Testing

The Administrator may require the manufacturer to test the vehicles or may require the vehicles be tested by EPA. The current practice is

for the manufacturer to conduct the tests but with EPA personnel supervising all the SEA testing. The manufacturer may accumulate up to 4,000 miles on each vehicle prior to emission testing. The method of accumulating the mileage is left to the discretion of the manufacturer. The manufacturer may retest each vehicle up to a total of three emission tests and may accumulate mileage between tests as long as the 4,000 mile limit is not exceeded. The final emissions result for a vehicle is determined by taking the average of all tests for a particular pollutant for the vehicle and then applying the appropriate deterioration factor, determined in the certification process, to this average. The vehicle fails if the result is above the applicable emission standard for that pollutant. As in the certification process, during testing in the 1981 and later model years, the EPA may adjust or cause to be adjusted certain adjustable engine parameters.

3. Passing-Failing Criteria

The current SEA regulations provide for a 40% Acceptable Quality Level (AQL). This means that in order to pass an audit no more than 40% of the vehicles tested can fail to comply with the applicable emission standard for a single pollutant. Although tests for HC, CO, and NOx are performed at the same time, each pollutant is treated separately in the acceptance or rejection process. By "treated separately" we mean that a vehicle which fails on one/two pollutants can still pass on the other two/one pollutants. With the 40% AQL, each vehicle tested could theoretically fail on one of the three pollutants, and the audit still be passed as long as no single pollutant's emissions exceeded its applicable standard in over 40% of the vehicles tested.

The number of vehicles that must be tested and the point at which an audit is failed or passed is determined by reference to 40CFR86 Appendix VIII, Tables I, II and III. In the event an audit is failed, there are various steps the Administrator may follow to suspend, revoke, and--after

compliance with the standards has been demonstrated--reinstate the vehicle's certification.

D. EXHAUST EMISSIONS MEASUREMENT PROCEDURE

The actual measurement of exhaust emissions for both the certification and SEA program are made while vehicles are operated on a dynamometer in a laboratory. The testing procures for certification and SEA are described in detail in 40 CFR 86 Subpart B (certification) and 40 CFR Appendices IX and X (SEA). Both test procedures are essentially the same except for small differences which take account of the fact that, unlike certification vehicles, SEA vehicles are production models that are not built with and cannot be permanently modified with any special features designed only to facilitate emission testing.

1. Federal Test Procedure

The following is a brief outline of the testing procedure:

a. Preconditioning:

Prior to testing, a series of procedures is followed to assure that all vehicles are in the same "condition" with respect to their fuel, temperature, and most recent driving schedule. This is done by draining and refueling the vehicles, driving them through a specified driving cycle---Urban Dynamometer Driving Schedule (UDDS)*, then storing the vehicle for between 12 and 36 hours inside the testing facility at a specified range of temperatures (cold soak).

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* The Urban Dynamometer Driving Schedule (UDDS) simulates a 7.5 mile urban trip. The UDDS is described in 40 CFR 86.115 and 40 CFR 86 Appendix I.

b. Emission Test:

After the preconditioning and cold soak parking the actual emissions test is made. The vehicle is pushed onto the dynamometer which has been set up to simulate the weight and air resistance of the particular vehicle. A tube is connected to the exhaust system of the vehicle to collect the exhaust gasses. The vehicle, which has not been started for at least 12 hours, is started and operated by a driver at the various speeds prescribed in the UDDS. The engine is then switched off. Exhaust gasses are collected for the entire trip including the initial startup. This constitutes the "cold start" portion of the test. After ten minutes the engine is restarted and the UDDS followed a second time. This constitutes the "hot start" portion of the test. The exhaust gasses from the various portions of the test are analyzed and the final result in grams of pollutant per mile computed by weighting the cold and hot start portions 43 and 57 per cent respectively.

E. HOW ACCURATE ARE EMISSION TEST RESULTS?

As we pointed out at the beginning of this Chapter, the variability of emission measurements is an important factor in determining the administrative feasibility of a NOx charge program. What is really of concern in evaluating emission testing in relation to imposing a NOx charge is the overall accuracy of the tests and the extent to which a test on one vehicle is applicable to another nominally identical vehicle. However, to gain an understanding of the overall accuracy, the components of the variability which make up the total variability must be examined. In this section we first examine the individual sources of the variability then turn to a discussion of the overall variability.

1. Sources of Variability in Emission Measurements*

The variability of emission test results can be separated into two general categories:

- Variability introduced by inaccuracies or uncontrolled variables in the emission test procedure; and
- Variability of the emissions of the automobiles themselves.

Since the overall variability of any emissions test is some combination of these two factors, it is difficult to determine the source or the magnitude of the contribution of the various sources of variability to the total variability. Thus, in many instances, it is not possible to attribute variabilities in test results to either the automobile itself or the test procedure. Given this caution we will discuss some of the major areas where variability is observed. This is not a technical description of the causes of the variability but more a phenomenological description of where the variability is found.

a. Variability Due to Automobiles Themselves

There are two possible types of variabilities related to the automobiles themselves:

i. Same Automobile Variability

Automobiles are not perfect machines. Thus even when an automobile in apparently the same condition is tested several times the emissions may be different.

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* Information in this section was drawn from references 15, 16, 17, 18, and 19.

ii. Vehicle-to-vehicle variability:

In mass producing supposedly identical automobiles it is not possible to make perfect copies. Each automobile is somewhat different and will have somewhat different emission characteristics.

Besides these unintentional differences resulting from the manufacturing process, there are many small differences, such as the type of tires, air conditioning, etc., which may not place vehicles in different emissions classes under the current classification system, but which may have some effect on the vehicles' actual emissions.

b. Variability Due to Emissions Tests

As with all measurements there are some inaccuracies in the emissions tests themselves. These inaccuracies can arise from inherent errors or lack of adequate control of variables in the prescribed measurement technique, and/or from improper conduct of the procedures. Obviously, not following the proper test procedure will cause unreliable results. But even if the designated procedures are followed there can be differences in the results obtained. Several examples of causes of these errors are:

i. Differences Between Drivers:

The driving schedule for the test is prescribed, but the driver is required to stay only within some tolerance range of the schedule. Thus slightly different driving schedules can be followed while still conducting the test according to the proper procedure.

ii. Differences in Ambient Conditions:

Temperature and humidity are controlled within ranges only. Barometric pressure is not controlled or specified. Properly conducted emission tests may thus be carried out under different conditions causing differing final results.

c. Variability Between Testing Facilities

Even though different testing facilities attempt to follow identical testing procedures, there are some statistically significant differences in the results obtained at different testing facilities. These have been observed in EPA's analysis of "paired data"[20] in which a comparison is made of the test results obtained when the same cars are tested by their manufacturers and then retested at the EPA testing laboratory. When a large number of cars are tested, this type of comparison will show if there is some real difference, not just random errors in the results obtained at the various labs. In the past, some significant differences have been identified for some pollutants between some laboratories.

EPA is working with the manufacturers to identify and eliminate the sources of these differences. These efforts have succeeded in decreasing the magnitude of differences but have not yet eliminated all differences. It should be noted that both positive and negative differences have been found when comparing EPA results with various manufacturers.

2. Quantifying the Variability

Up to this point we have avoided any attempt to quantify emission measurement variability. As we have pointed out, there is no overall number that can be attributed to all emission testing. We report below the results of several investigations into the variability question to give some idea of the magnitudes that have been found, and discuss

some of the statistical factors that relate to the accuracy of emissions tests. One important issue raised involves the question of how the variability of emission measurements can be expected to change as the overall level of NOx emissions decreases.

a. Repeat Tests of Same Automobile

A recent SAE Technical Paper[16] reports the results of repeated tests of the same automobile. Each of four automobiles was tested approximately 20 times at the same laboratory using five different test cells within the laboratory. These tests show the standard deviation for NOx results to be approximately 10% of the mean value at emission levels ranging from about 1.2 to 1.9. Assuming that 10% represents the population standard deviation, one can estimate the size of the confidence interval in which the true mean lies when different numbers of repeat tests are performed. An example is given in Table IV-2 where a measured mean of 1.5 grams/mile (approximately the overall mean value in the SAE Report) is assumed, and the standard deviation is taken as 10% of that mean (1.5 x 10% = .15).

The calculation in Table IV-2 was made assuming the standard deviation of the population is known. In practice this is not the case. It cannot be assumed that the standard deviation of the emissions of NOx or any other pollutant will be the same for different vehicles. Thus the standard deviation as well as the mean must be estimated. This increases the number of tests that must be performed to obtain an estimate of the mean emissions of the same reliability as in the case when the population standard deviation is known.

TABLE IV-2. CONFIDENCE INTERVALS FOR TRUE MEAN WHEN MEASURED MEAN = 1.5 GRAM/MILE AND STANDARD DEVIATION = 0.15 GRAM/MILE

(Normal distribution assumed)

Number of tests	Confidence Interval (grams/mile)		
	95% Confidence level	80% Confidence level	67% Confidence level
1	1.5 ± .29*	1.5 ± .19*	1.5 ± .15*
2	.21	.14	.10
3	.17	.11	.08
4	.15	.10	.07
5	.13	.09	.07
10	.09	.06	.05

* Rounded to nearest hundredth.

b. Deterioration Factor Uncertainty

The deterioration factor (DF) established for each engine family in the certification process is used both in the certification procedure and in audits under SEA. The statistical reliability of the DF will depend on the accuracy of the individual tests made at 5,000 mile intervals during the accumulation of a total of 50,000 miles. For example, Sketh and Rice[16] have shown that, based solely on statistical arguments and the following assumptions: 1) Individual test results normally distributed; 2) Standard deviation of each measurement equal to 33% of the mean of each test; and 3) The true DF equal to 1, that, at an 80% confidence level, the apparent (measured) DF can range from 1.6 to 0.6. In practice, the variability of the population is unknown and the confidence interval of the DF must be calculated from statistics computed in the least squares regression analysis used to compute the DF. These statistics are not

currently reported with the DF's determined for use in the current certification and SEA programs.

Besides the question of the accuracy of the DF computed from the testing of one vehicle, there is the question of whether or not that one vehicle's DF is the same as the DF of other models in the engine family.

c. Type of Distribution

We have assumed to this point that emission measurement results are normally distributed. This is not necessarily the case as was demonstrated in a VW[19] study which found some sets of emission results to be better represented by a skewed distribution than by a normal distribution. Doug Berg commented in a 1978 paper[15] on this topic that emission results "are difficult to classify according to distribution and often defy common sense."

It is not known how great an error is introduced by using the assumption of normality. In many cases the error may be small, but more work is needed to establish the properties of the distribution. This is especially true in conjunction with any consideration of lowering emission standards. No vehicle can have emissions that fall below zero grams/mile. Thus there is a lower limit on emissions while there is essentially no upper limit. As emissions are lowered, the distribution may tend to become sufficiently skewed to make the assumption of normality introduce significant errors.

d. Is Variability Relative or Absolute?

A related question involves the accuracy of the overall emission test measurements as the level of the emissions is decreased. The question is whether the accuracy tends to be a constant percentage of the

mean value or a fixed amount. For example, assume the accuracy of NOx measurements was determined to be ± 10% or ± 0.2 at an emission level of 2.0. This can be written as either of the following:

2.0 ± 10% or
2.0 ± 0.2

Now assume that NOx emissions were successfully reduced to 0.4. Would the accuracy of the measurements be ± 10% of the new lower NOx level of 0.4 or would they be of the same absolute magnitude (± 0.2) as at the 2.0 level? In other words, would the uncertainty in the measurements be:

0.4 ± 10% which is equivalent to 0.4 ± 0.04 or
0.4 ± 0.2 which is equivalent to 0.4 ± 50%?

There is not sufficient experience with low emission levels around 0.4 NOx to answer this question. As with much of the uncertainty in emission measurement, the answer will probably depend on many factors of which the variability of the low NOx emitting vehicles themselves will be a prime determinant.

3. Overall Testing Accuracy

In this section we discuss the appropriateness of using certification test results as a basis for the NOx charge and present some general comments on the interrelationship between a NOx charge and the accuracy of emission measurements. Certification results are selected for discussion since the certification program is by far the most comprehensive, in terms of the vehicle models tested, of any of the current programs.

a. Do Certification Results Represent Production Models?

The certification procedure attempts to find the emissions of one prototype vehicle representing each group of vehicles within an engine family that may have significantly different emission levels. Even if the emissions of the certification vehicle are accurately determined, one is not assured that all assembly line production vehicles will have the same emissions. There will be differences between the different production vehicles themselves, and there may well be a difference between the mean value of the emissions of the production vehicles and the certification vehicles. The magnitude of all these differences depends on many factors (e.g., quality control, similarity of production line practices to certification vehicle assembly practices, and the accuracy and number of emission tests conducted). These factors are difficult to quantify and depend on the actual case under consideration.

The important question is: "Do the certification test results accurately reflect the emissions of vehicles coming off the production line?" As pointed out above, there is no universal answer to this question. One indication of the correlation between certification results and "actual" emissions could be found by a comparison of certification and SEA results for the same vehicle model.

b. General Comments on Emission Measurement

What one would like in determining the best type of NOx charge program to adopt from the point of view of compatibility with emissions testing is the overall accuracy of an emission test. This number is not now available, and, in fact, no single number will be universally applicable since the answer depends on many variables such as the care with which the vehicle being tested has been constructed, the laboratory doing the testing, the absolute emission level, etc.

We have not been able to determine the current level of accuracy of routine testing. One major problem in this regard is that the goal of emissions testing is to determine if vehicles meet current standards (i.e., have emissions below some level). The goal is not to determine the absolute levels of those emissions.

If a charge is imposed based on the level of NOx emissions, a more accurate determination of the emission level may have to be made than is the case under the current pass/fail system. The variability of emissions measurement due both to the variability of emissions actually emitted by the vehicle and due to the variability of the emissions tests themselves becomes of prime importance in determining the feasibility and type of charge program. If the variability of emissions measurements is sufficiently large to cause significant differences in the charges paid, multiple testing or a charge based on some measure of average emissions may have to be employed to ensure an equitable charge program.

F. HOW DO MANUFACTURERS DEAL WITH THE STATISTICAL NATURE OF EMISSIONS MEASUREMENTS?

Manufacturers must consider the statistical nature of emissions and emissions testing when designing their vehicles to pass EPA emissions tests*. For example, even though the certification test is not a "statistical" test in that a vehicle can pass by passing a single emission test, the manufacturer must design the vehicle with some margin of safety to account for emissions variability. This is illustrated in figure IV-1, where a hypothetical probability distribution of emission test results is plotted.

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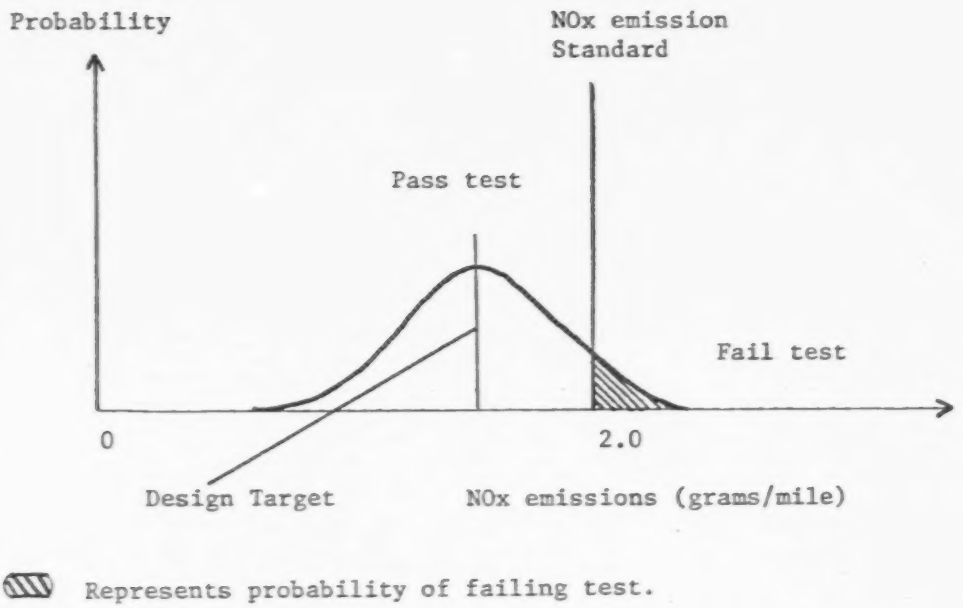
* See references 16 and 19.

FIGURE IV - HYPOTHETICAL ILLUSTRATION OF CRITERIA USED TO SELECT A DESIGN TARGET FOR NOx EMISSIONS



The manufacturer must include his estimates of the variability of the testing procedure and the variability of his vehicle's actual emissions, along with an acceptable level of risk of failing a certification test as part of the input to his decision in selecting a design target for emissions. If the manufacturer knows there is some constant difference between the emission results obtained at his laboratory and the results obtained at EPA's testing facility, this must also be taken into account in setting a design target. The same type of considerations, including an estimate of the variability of the emissions of production models, must be included in setting the design target with reference to SEA regulations.

In essence, under the current EPA pre-sale testing programs, it is the manufacturers, not EPA, who must deal with the statistical nature of emissions measurements. If the emissions program were changed in such a way that EPA needed to determine actual emission levels, EPA would have to deal with the statistical nature of emissions measurements. Depending on the level of accuracy required, this could lead to a major change in the emission testing program.

V. PREDICTING THE RESPONSES OF CONSUMERS AND MANUFACTURERS TO A NOx CHARGE

To estimate the economic and environmental impacts of any NOx charge program, the response of consumers and manufacturers to the charge must be predicted. In this chapter we discuss the criteria which will determine the responses of both groups and state some assumptions that can be made concerning the responses.

A. CONSUMERS

A reasonable assumption to make with regard to the behavior of consumers is that while consumers may value clean air in general, they place much more value on other aspects of an automobile than on its emission characteristics. Thus, unless some regulatory and/or economic sanctions are imposed, the level of exhaust emissions plays a relatively minor part in the consumer's selection of a particular automobile. The factors relevant to the response to a NOx charge that consumers do consider in their purchase decisions are: sticker price, expected maintenance costs, fuel economy, and drivability. The "cost", as perceived by the consumer, of any emission control device is taken as some combination of the effects the control device has on these four factors. The relative weights given to these four factors will differ among consumers.

B. MANUFACTURERS

Manufacturers will respond to consumer preferences by manufacturing automobiles with the combination of initial costs, expected maintenance costs, fuel economy, and drivability that the manufacturers perceive as the most desirable to the consumer. In the case of a NOx charge imposed on manufacturers, unless they are restricted by some competitive pressures, manufacturers will pass through to consumers, in the form of increased sticker prices, at least some portion of the costs of emission

control equipment and/or the costs of any NOx charges.

1. Responses to Specific Circumstances

Using the above observations and assuming manufacturers will respond to a charge so as to minimize costs ("Costs" are composed of the four factors: initial cost, maintenance cost, drivability "cost"* and fuel economy "cost", described above), we examine two possible situations.

a. Control Equipment Affects Only Initial Cost

We first look at the simple case where a control system adds to the initial cost but does not affect maintenance costs, fuel economy, or drivability. The installation of the device will result in a reduction in the amount of the NOx charge owed. The manufacturer will tend to:

- Install the device if the cost of the control device is less than the reduction in the NOx charge owed.
- Not install the device if the cost of the control device is greater than the reduction in the NOx charge owed.

To actually induce the manufacturer to install the device, the expected cost saving (NOx charge saved minus cost of control device) would have to be sufficient to compensate for the risk of installing the device as opposed to the certain course of not installing the device and paying the known NOx charge. This argument assumes that consumers place little or no value on emissions levels when purchasing an automobile. A greater public awareness of the problem of pollution caused by automobiles may lead to consumers valuing automobiles with low emissions.

*It is recognized that an explicit quantitative accounting for drivability is difficult to obtain.

b. Control Equipment Affects Both Initial Cost and Fuel Economy

When factors besides the initial cost are involved, the situation is more complex. One of the more difficult costs associated with emissions control equipment to evaluate involves the effects on fuel economy of control devices.

To achieve any one level of emissions there is generally a choice of control technologies with the more costly technology having the least adverse effect on fuel economy. The manufacturer must decide whether the increased cost of the "better" control technology is offset by the relative fuel economy benefit. The manufacturer's perception of the market will determine which of the possible control systems is selected by the manufacturer. Under a system where emissions are governed by regulatory standards, the same level of emission control must be accomplished no matter which control technology is selected.

Under an economic incentive system, such as a NOx charge program, the situation is more complex. Besides the trade-offs between the initial cost of emissions control equipment and fuel economy, the manufacturer has the additional option of choosing what level of NOx emissions he will strive for and, consequently, what NOx charge he will pay. Where tradeoffs between emissions control and fuel economy exist, the costs associated with different levels of fuel economy (particularly at fuel economy levels more efficient than the standard) then become an important factor in determining what level of emissions will be achieved.

As a simple example, take two cars--H and L--that are alike in all aspects, including initial cost, except for their levels of emissions and fuel economy.

	Car H	Car L
NOx Emissions	1.0 gpm	0.4 gpm
Fuel Economy	30 mpg	26 mpg

Since the initial purchase price is the same for each car, most consumers would select car H because of its fuel economy advantage. The question becomes, "How much of a charge must be imposed on car H to make the consumer indifferent between the two cars?" In theory the elasticities related to initial cost, and fuel economy can be used to answer this question. However, considering the uncertainty in the availability of fuel, it is doubtful that a reasonable estimate can be made of the relative value consumers place on fuel economy.

The situation described above should not be a significant problem in terms of choices involving the conventional spark ignition engine. Experience to date shows that as expertise is gained with the control technologies, the effects on fuel economy can be minimized. However, the situation is different when other types of engines are considered.

For example, consider the choice between a diesel engine and a conventional engine. Some consumers are currently willing to pay the initial cost premiums for a diesel powered automobile to gain the substantial fuel economy of the diesel. Techniques for controlling NOx emissions to low levels in diesels are not as well developed as those for controlling conventional engines. If NOx control techniques that do not seriously affect the fuel economy of the diesel are not developed or if these controls prove to have a much higher initial cost than controls for conventional engines, manufacturers may opt to expand the use of diesels and simply pay the NOx charge in order to realize the fuel economy benefits of the diesel. The basic point here is that a NOx charge that is sufficient to induce the lowering of NOx emissions from conventional engines may not be sufficient to elicit the same

response where other types of engines are concerned. This is discussed further in Chapter VI, Section I.

2. Will Manufacturers Adopt "Least Cost" Approach?

In the discussion thus far we have assumed that if the costs attributed to the control device can be determined, the manufacturer, under a charge program, will react to minimize his total costs (costs attributed to control equipment plus amount of the NOx charge owed). This is a reasonable assumption but other responses are also possible.

The development and installation of improved emission control equipment involves the use of many types of resources, such as money, production and research facilities, and trained personnel. However, the incremental costs of storage, labor, etc., associated with further NOx control are not likely to be particularly high (there are already large scale costs). This is because, for example, adequate storage in already existing facilities is likely to be already generally available. Hence a charge based on the direct costs of NOx control may be sufficient to induce the desired behavior. There is also the risk that the control equipment will not perform as well as expected. Paying the NOx charge, on the other hand, only involves expending a known amount of money. Given these facts, a manufacturer might decide that it was actually "cheaper" to do nothing to reduce NOx emissions, pay the NOx charge and devote his resources to improving some attributes of his vehicles which he felt would enhance their value to consumers more than the "cost" of the NOx charge.

Whether or not this type of situation will arise depends on the magnitude of the NOx charge as compared to the "cost" or reducing emissions. The significant point here is that all costs must be considered to have assurance of inducing the desired behavior from the manufacturers.

C. NOx CHARGE - SALES IMPACTS

Any measure requiring the automobile industry to make expenditures that do not result in a commensurate improvement in the desirability of their products from the point of view of consumers will have some negative impact on the industry. The industry can absorb the increased costs, thereby reducing their profit margin, pass the cost through to the consumer, thereby risking some loss in sales, or adopt some intermediate course, where some of the costs are absorbed and the remainder passed through. The strategy will depend on the price elasticity of demand.

Impacts on the industry from the pass-through of pollution control costs can be expected from three sources:

- loss of sales due to increases in selling price (cost of control equipment plus any NOx charge);
- loss of sales due to consumers' perception of a decrease in value resulting from any adverse effects of emission control devices (decrease in fuel economy, adverse effects on drivability, and increase in maintenance expenses);
- loss of sales due to the diversion of financial and personnel resources to developing emission control technologies rather than developing features more desirable to the consumer.

1. Impact on Total Sales

One method that has been used to estimate the impact of changes in purchase price, fuel economy, maintenance costs, and "other factors" on sales is the Ford Econometric Model.* This single equation model relates percentage changes in the above factors to expected percentage changes in

*Presented by Ford Motor Co. in submissions to the 1977 Suspension Hearing Panel, letter of January 19, 1975. While this model may now be somewhat dated, it is illustrative of the magnitude of sales effects that could result from a NOx charge.

sales. The model can be used to predict changes in sales in the short-term (first year after a change in one or more of the factors) and in the long-term (second and succeeding years after a change in one or more of the factors). The model is given by:

$$\Delta \text{ Sales } (\%) = \varepsilon \, (0.5 \, \Delta \text{ Price } (\%) + 0.3 \, \Delta \text{ fuel economy } (\%) + 0.1 \text{ maintenance Costs } (\%) + 0.1 \, \Delta \text{ Other Factors } (\%))$$

equation V-1

Where:

ε = -0.7 short-term (first year)

= -0.35 long-term (second and succeeding years)

Δ Sales (%) $\equiv$ expected percentage change in sales

Δ Price (%) $\equiv$ percentage change in purchase price

Δ Fuel economy (%) $\equiv$ percentage change in fuel economy

Δ Maintenance costs (%) $\equiv$ percentage change in maintenance costs

Δ Other factors (%) $\equiv$ percentage change in other automobile attributes

Besides purchase price, fuel economy is the most important factor in the model. Available estimates of the effects on fuel economy resulting from decreasing NOx emissions from 1.0 to 0.4 gpm range from decreases to increases in fuel economy. Because EPA predicts no negative fuel economy effects from emission controls with advanced catalyst technology, we assume the purchase price is the only variable affecting sales in the model. Under this assumption the model reduces to:

$$\Delta \text{ Sales } (\%) = \varepsilon \, (0.5 \, \Delta \text{ Price } (\%))$$ Equation V-2

where the symbols have the same meaning as above.

In Table III-2 of Chapter III, we presented estimates of the incremental cost of reducing NOx emissions from 1.0 to 0.4 gpm. These estimates range from 0 to $183. Changes in purchase price of $90 and $180 were inserted in equation 2 to make the estimates shown in Table V-1. The base purchase

price of an automobile was taken to be $ 7,000.

TABLE V-1. ESTIMATES OF EFFECT OF NOx CHARGE ON SALES*

Purchase Price Without NOx Charge ($)	Incremental Price Increase Due to Charge† ($)	Percentage Price Change Due to Charge† (%)	Short-term‡ Percentage Sales Change Due to Charge† (%)	Long-term§ Percentage Sales Change Due to Charge† (%)
7,000	90	+1.286	-0.450	-0.225
7,000	180	+2.571	-0.900	-0.450

*Estimates made using form of Ford Model shown as equation V-2.

†Amount of charge and/or cost of emission control equipment

‡Effect in first year ($\varepsilon = -0.7$)

§Effect in second and succeeding years ($\varepsilon = -0.35$)

The results in Table V-1 show a maximum expected sales decrease of 0.9% in the first year for a price increase of $180. In all other cases the sales decrease is less than 0.5%. These effects are negligible and within the tolerance level of error in the model.

2. Impact on Individual Manufacturers

Besides the effect on sales, profits, employment, etc. in the auto industry as a whole, a significant issue that must be considered when imposing more stringent environmental requirements is whether these requirements will impose undue burdens on particular manufacturers. The development of new technologies requires an initial R&D effort and upfront expenditure of capital and personnel resources. This R&D effort is essentially a fixed cost (i.e., independent of the number of control devices actually produced).

Both these factors introduce economies of scale into the development of new emission control technologies and tend to favor the largest firms. Whether this amounts to a significant advantage will depend on many factors, such as the difficulty of the emission control problem and the time frame within which the problem must be solved. No model for estimating individual auto company responses to a cost increase was available.

VI. DEFINING THE COMPONENTS OF A NOx CHARGE PROGRAM

The variables or components that make up a complete NOx charge program are identified and discussed in this chapter. Included with the discussion of the components are comments as to the most appropriate approach to take with respect to each variable. A list summarizing the components and conclusions appears at the end of this chapter in Section L.

Two limitations to the scope of this study are stated before proceeding:

- The study is limited to charges based on testing performed before the point of sale to the consumer. An assessment of charges based on the results of in-use sampling or inspection/maintenance programs is not considered.
- We only consider applying a NOx charge at emission levels below the current statutory 1981 standard of 1.0 NOx. We also take the research goal, 0.4 NOx contained in the Clean Air Act as the lowest NOx emission level for which a charge can be levied. For emissions below 0.4, only rebates and/or credits are considered. As far as emission levels of HC and CO are concerned, we take the 1981 standards as remaining fixed. Thus, the standards between which a charge may be assessed are .41/3.4/1.0 and .41/3.4/0.4. Credits and/or rebates may apply between .41/3.4/0.4 and .41/3.4/0.0.

A. TYPES OF CHARGE SCHEDULES

Three types of charge schedules are discussed in this section. These are:

- Sliding schedule where the charge is directly (and linearly) proportional to the NOx emission level;
- On-off schedule, where 100% of the charge is assessed when emissions are above a certain level and zero charge is paid if the emissions are below that level;

- Stepped schedule, where the charge is the same for certain ranges of emission levels and changes discontinuously between ranges. From a practical viewpoint, because of the small range between 1.0 and 0.4 grams/mile and the imprecision of emissions testing, when many steps are included, the stepped schedule becomes indistinguishable from the "sliding schedule".

These types of schedules are shown schematically in Figure VI-1.

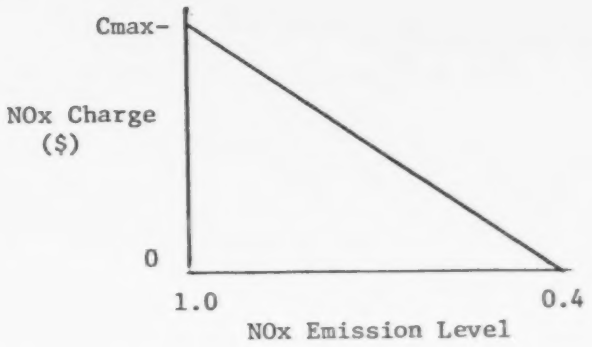
There are, of course, other schedules; however, we limit our discussion to the three described in Figure VI-1. We will examine the pros and cons of the basic characteristics of each type of schedule. Specific schedules will then be selected for inclusion in the complete NOx charge programs discussed in a later chapter.

1. Costs of Emission Control May Vary Discontinuously

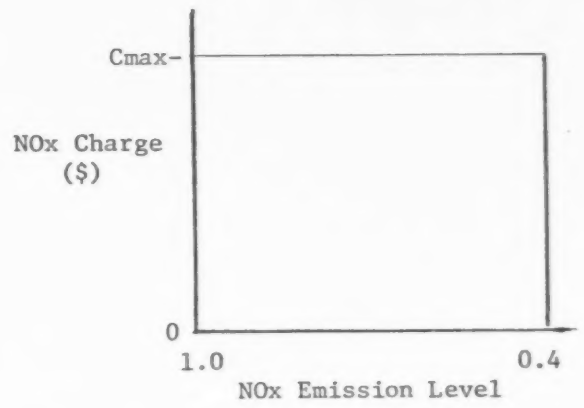
An aspect of emission control technologies that is important when choosing a charge schedule is that the level of emissions control is "lumpy". One particular control system will have a limited range of control capabilities. A different control system may have a different range of control capabilities. The introduction of an improved control system may cause a discontinuous change in the level of emissions. This is illustrated schematically in Figure VI-2.

Even if the capabilities of the two technologies overlap, the cost of the controls does not vary continuously with emissions (Figure VI-3). Figure VI-3 shows costs increasing as emissions are decreased. In the short run, this is generally the case, but in the long run, as existing technologies are improved and new technologies are developed, costs need not necessarily increase.

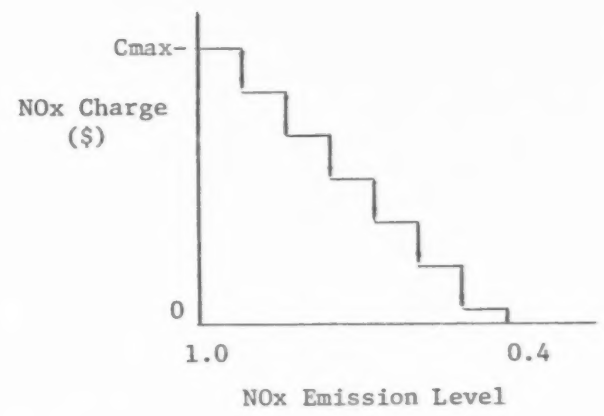
FIGURE VI-1: TYPES OF CHARGE SCHEDULES CONSIDERED



SLIDING CHARGE SCHEDULE



ON-OFF CHARGE SCHEDULE



STEPPED CHARGE SCHEDULE

FIGURE VI-2: ILLUSTRATION OF "LUMPINESS" OF CONTROL TECHNOLOGIES

Emissions control above 0.8 NOx can be accomplished with Technology I. To decrease emissions below 0.8 fine tuning of Technology I is not sufficient and a different technology, Technology II, must be employed.

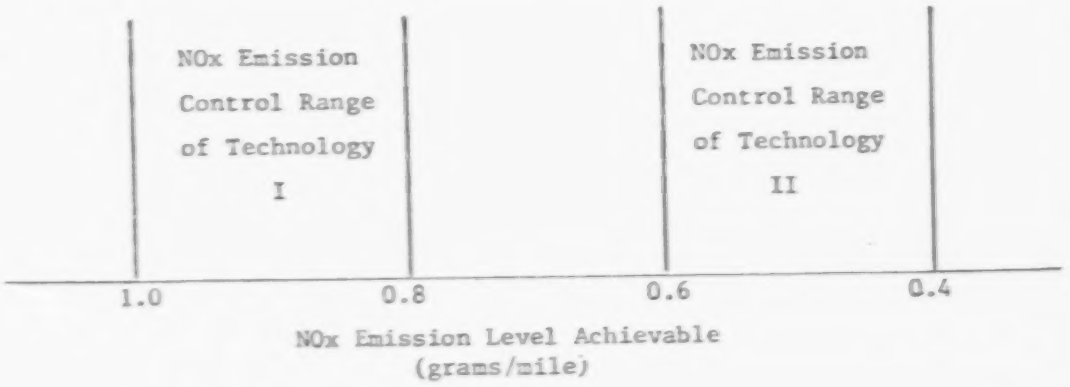
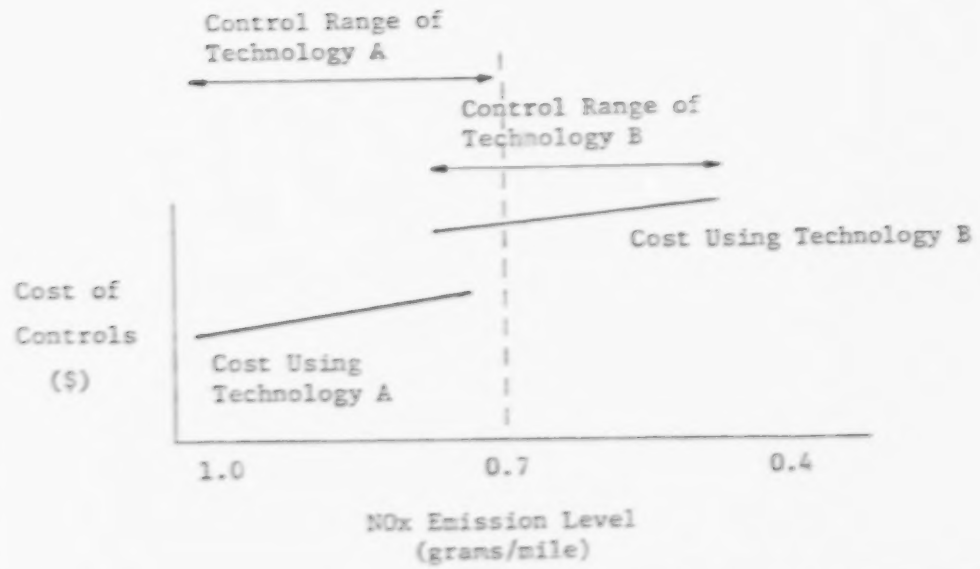


FIGURE VI-3: ILLUSTRATION OF DISCONTINUOUS CHANGE IN THE COST OF CONTROLS



We reiterate here that "cost" includes factors other than the initial cost of the control equipment, such as the effects on driv bility, fuel economy, and maintenance. In fact, improvements in fuel economy, drivability, and reliability are in many instances the main benefits of new technologies.

2. The Effect of Discontinuous Cost Variation on the Selection of a Charge Schedule

The significance of the lumpiness of emission control costs with respect to the type of charge schedule concerns the response of manufacturers to the charge. With a sliding scale schedule, the manufacturer may choose to make minor improvements in his existing control systems to reduce his charge liability as much as possible, without investing the time and resources and without assuming the associated risks to develop and install new advanced emission control technologies. On the other hand, a stepped or an on-off schedule, if properly designed, would eliminate benefits accruing from small changes in emissions and thereby encourage new technologies capable of reducing emissions sufficiently to reach the next "step" of the schedule or avoid the charge altogether.

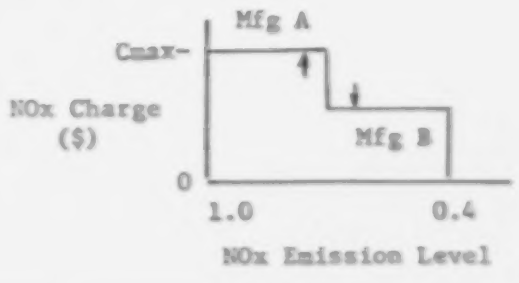
One drawback to a stepped or on-off schedule is that more information on the technical capabilities and costs of future control systems is required to design the system than for a sliding scale schedule. One of the primary reasons for using a stepped or on-off schedule would be to force the introduction of new technologies and reduce the incentive for making only marginal improvements in current technologies. Consequently, some estimates of the emission levels at which new technologies are needed and the costs of these technologies would be required to have the charge schedule correspond roughly with the cost schedule.

3. Effect of Emission Measurement Variability on the Selection of a Charge Schedule

Besides the lumpiness of emission control costs, the other major factor in deciding on a charge schedule is the problem of the inexactness of emissions measurement discussed in Chapter IV. The question is, "Given that emission results do not include adequate sampling to establish an accurate mean value for the emissions of the actual production automobiles for each model, is one type of schedule superior to other types?"

A related factor is the response of automobile manufacturers to the uncertainty in the testing procedures and variability between automobiles. A manufacturer facing a regulatory standard above which he cannot market his automobile will take pains to build some margin of safety into his control system to allow for some test variability and still pass the test. An on-off or stepped charge schedule can be expected to elicit the same response. Thus, one can argue that an on-off or stepped charge can be equitable and not impose arbitrary costs or benefits due to testing variability. However, suppose a manufacturer miscalculates slightly and the emission test results indicate he just misses getting to the next step in the charge schedule. In this case, an insignificant difference in the measured emission level can lead to a large difference in the charge owed. This is shown schematically in Figure VI-4.

FIGURE VI-4: SMALL DIFFERENCE IN EMISSION--LARGE DIFFERENCE IN CHARGE



4. Conclusion

Sliding, on-off, and stepped schedules are all reasonable. Each has its advantages and disadvantages:

- Sliding Scale Schedule has the advantage that small changes in emission levels do not lead to large jumps in charges owed. Also, the total charge owed by a manufacturer is the same no matter whether the charge is based on the emissions of individual vehicles or on the manufacturer's sales weighted average emissions. A possible disadvantage is that the maximum charge may have to be very high to induce emissions reduction all the way to 0.4 NOx.

- On-Off Schedule may be the most appropriate to reduce all emissions to 0.4 NOx. A very small change in emission levels, near the one step in the schedule, can cause a large shift in charges due. There is no inducement to reduce emissions if the "step' cannot be reached.

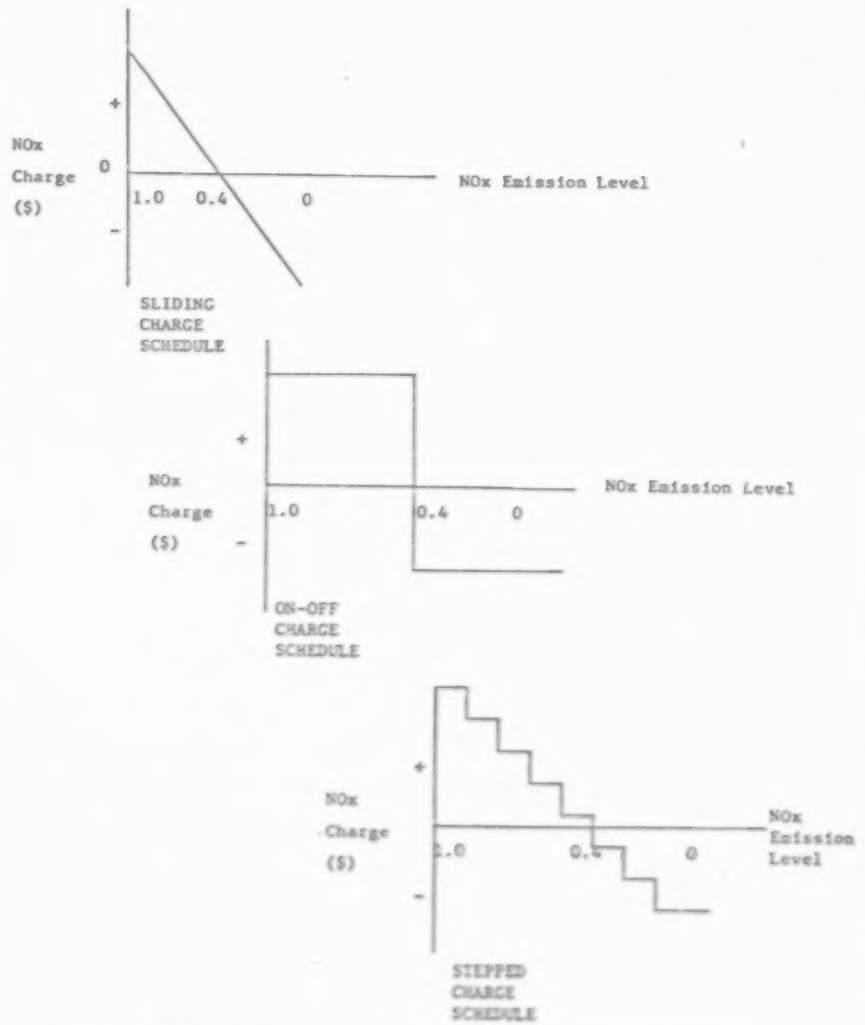
- Stepped Charge Schedule has characteristics intermediate to the Sliding and On-off schedules.

B. REBATES OR CREDITS FOR LOW EMISSIONS?

To maintain incentives to reduce NOx emissions no matter what the absolute level of emission, the three basic types of charge schedules can be modified to allow rebates or credits for vehicles that have low emissions; that is, they "beat" the standard. Figure VI-5 illustrates the three basic schedules modified to allow rebates or credits. The rebates and credits are shown as negative charges in the figure. The differentiation we make between a "rebate" and a "credit" is the following:

- A rebate is payable in cash;
- A credit can only be used to offset charges owed due to NOx emissions. No cash payments are made for credits earned

FIGURE VI-5: THREE CHARGE SCHEDULES
MODIFIED TO ALLOW FOR REBATES OR CREDITS



The issue of rebates vs. credits is moot for any manufacturer whose NOx charges owed exceed rebates or credits earned. The question is only relevant when a manufacturer predominately sells low NOx emitting automobiles. In this instance, although the government would collect and disburse the payment, a rebate system or an inter-company credits system would in reality involve transfer payments or credits from manufacturers with net positive NOx charges owed to manufacturers with net negative NOx charges owed. Two possible situations could develop which raise concerns that argue strongly against including any provision for rebates or inter-company credits in a NOx charge program:

- Balance of Payments Concerns associates with rebates or inter-company credits to foreign manufacturers; and
- Anticompetitive Concerns (e.g., an "unhealthy" manufacturer making payment to a "healthy" manufacturer.)

A credit that can be applied to NOx charges owed by an individual manufacturer has the advantage of not allowing for any direct payments to any manufacturer, while at the same time, under most conditions, maintaining incentives to reduce NOx emissions. Such credits can also enhance the economic efficiency of a charge program since manufacturers are encouraged to control emissions below 0.4 on some vehicles if the cost of controlling these vehicles is less than controlling other vehicles with higher emission levels.

Conclusions:

- While a rebate-type system has attractive characteristics, it is probably unfeasible.
- Intra-company credits may be a reasonable option.

C. SHOULD THE CHARGE BE PHASED-IN?

Any program may need to be adjusted for inflation, but there is a more fundamental question of whether or not the NOx charge should be phased-in with the charges in terms of constant dollars increased over time, and/or the emission levels at which the charge is applied reduced over time.

The three basic schedules showing an adjustment where the maximum charge is left unchanged and the applicable emission levels are changed are shown in Figure VI-6. Credits are not shown in the figure, but they can easily be added.

FIGURE VI-6: CHARGE PHASED-IN BY LOWERING APPLICABLE EMISSION LEVELS (NUMBERS 1, 2, and 3 INDICATE SUCCESSIVE TIME PERICDS)

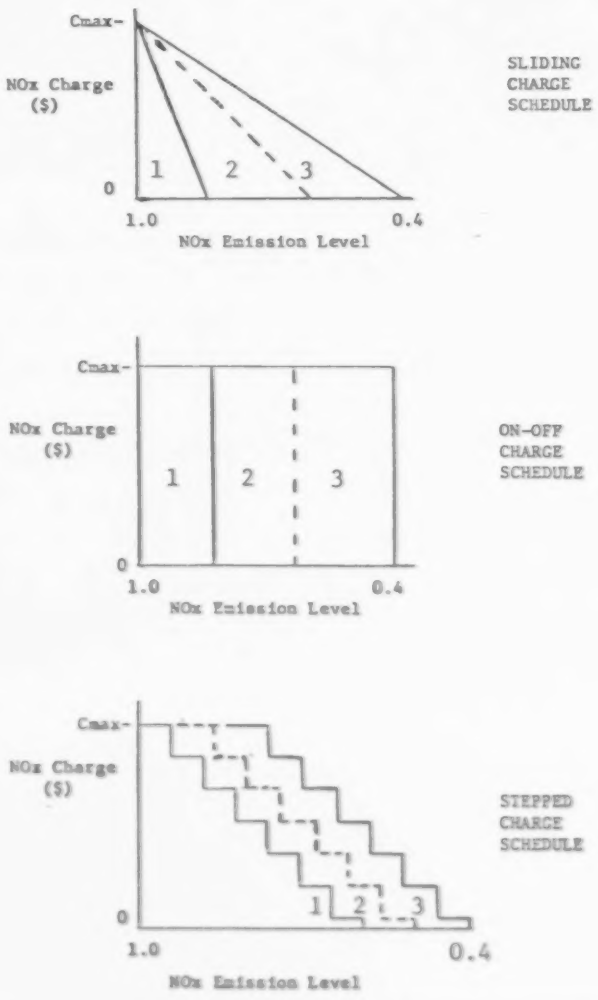
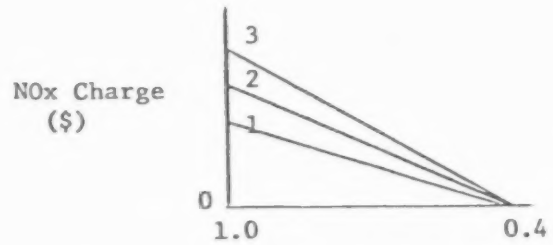
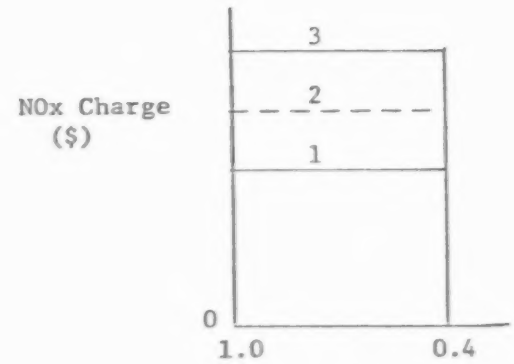


Figure VI-7 shows phased-in schedules where the primary change is in the level of the charge. Provisions for rebates and credits can also be added.

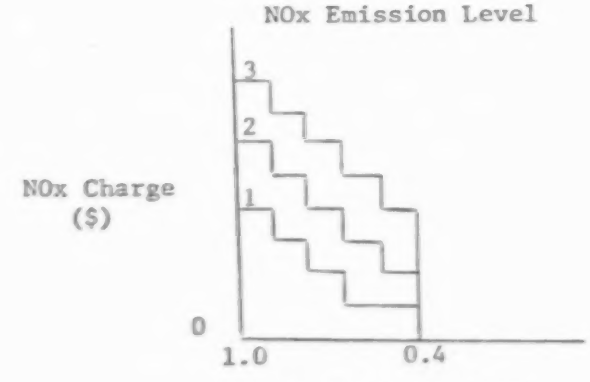
FIGURE VI-7: CHARGE PHASED IN BY INCREASING LEVEL OF CHARGE



SLIDING CHARGE SCHEDULE



ON-OFF CHARGE SCHEDULE



STEPPED CHARGE SCHEDULE

Since there are uncertainties in the costs and capabilities of various control systems and uncertainties as to the manufacturers' responses to various levels of a NOx charge, one method to find the right level of the charge is to initially set the charge at a fairly low level then increase the charge to a point where manufacturers take some action. This is inefficient (and probably politically infeasible) in that during the initial period charges are collected and no action is taken. Consumers pay higher prices but receive no benefit. The charge should be imposed initially at a level that is estimated to elicit real responses from the manufacturers. As time proceeds, the charge can be tightened to induce continued responses by the manufacturers.

Conclusions:

The charge may be phased in, but the initial level of the charge should be high enough to elicit some real response.

D. WHEN SHOULD THE CHARGE BE IMPOSED AND HOW LONG SHOULD IT LAST?

The initial time that the NOx charge is introduced must be carefully considered. If the charge is imposed with too short a lead time, the manufacturers will not have time to respond, and consumers will pay higher prices with no benefits. Thus, the charge should be announced far enough before its implementation date to permit real change in the control equipment. A longer time frame may be used, depending on the perceived urgency in the need to control NOx emissions below the statutory 1981 1.0 gpm level. Some of the questions as to the timing of the charge will be answered when EPA finishes its review of the need for a short-term NOx standard.

The next question involves the duration of the charge. Assuming it is determined by EPA that the 0.4 NOx level must be met, the charge can

either be imposed permanently, with yearly escalating rates that will eventually price nonconforming automobiles out of the market place, or the charge can be used as a temporary transition measure that is followed by a regulatory standard of 0.4 Nox.

Conclusion:

When - not determined, but sufficient lead time should be included to allow manufacturers to respond.

How long - Replaced by regulatory standard.

E. WHAT EMISSION TESTING PROGRAM IS NEEDED?

The scope of this study is limited to establishing NOx charge program that relies only on presale testing for the determination of the emissions charge. The possible options are essentially limited to using the current EPA presale testing procedures (certification and/or SEA) or designing some new testing procedure that is entirely different or merely expands some of the current testing programs. These possibilities are listed below:

- Use current EPA programs...
  - Certification test results
  - Certification plus SEA results (the current SEA program cannot be used alone since all models are not covered)
- New testing procedure
  - Expand certification or SEA testing
  - Separate testing program for NOx charge

The current certification program test results are the most attractive basis for the charge, since it is the only current program that attempts

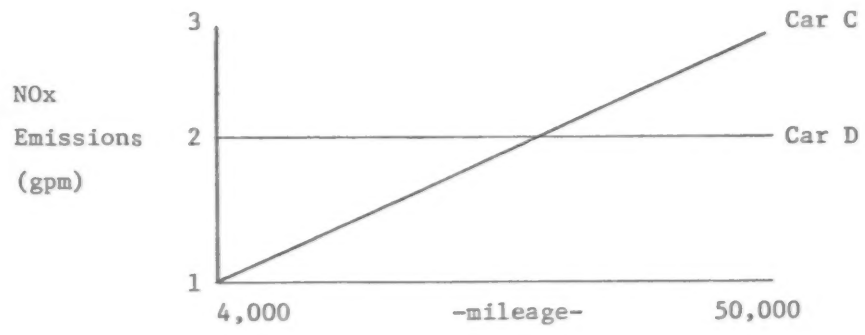
to be comprehensive in terms of the vehicle models covered. However, for concerns regarding certification testing as the basis of the charge see Chapter IV.

Conclusion: No determination made.

F. WHAT EMISSIONS MEASUREMENT SHOULD BE USED TO ASSESS THE CHARGE?

The level of exhaust emissions can change over the life of an automobile. If all automobiles showed the same rate of change in emissions with mileage, it would make no difference if a charge were imposed on the basis of emissions at low or high mileage. However, different automobiles do exhibit different rates of emissions changes and, consequently, it becomes an issue to determine whether to base the charge on the emissions rate at some particular mileage or on some average emissions rate over the life of the car. This problem is illustrated in Figure VI-8.

FIGURE VI-8: SCHEMATIC SHOWING DIFFERENT EMISSION CHARACTERISTICS OVER THE LIFE OF AN AUTOMOBILE



A charge imposed on the basis of emissions at 4,000 miles would favor Car C. At 50,000 miles, however, Car D is favored. If the total emissions between 4,000 and 50,000 miles is used, the two cars pay the same charge.

The environmental damage associated with each car is best reflected by the total emissions over the life of the car. This would imply using the area under the emissions (gpm) vs. mileage curve as the basis for imposing the charge. This basis has the advantage of not arbitrarily favoring one type of engine or control system. However, several practical problems must be considered.

1. Practical Options for Assessing the Charge

The 4,000 and 50,000 mile points were selected in the example (Figure VI-8) because, as was previously discussed, these are the mileages used in current EPA certification procedures. Fifty thousand miles is defined in the Clean Air Act as the useful life of an automobile, although actual automobile life is generally longer. The total emissions for the actual, in-use, life of the automobile are theoretically the most reasonable measure for applying any charge. However, we feel that a NOx charge program, to be feasible, must fit into the over-all testing procedure. This precludes requiring tests to greater than 50,000 miles. Within this restriction, there are three reasonable alternative measures on which to base the charge.

- Emissions at 4,000 miles
- Total emissions between 4,000 and 50,000 miles
- Emissions at 50,000 miles

a. Emissions at 4,000 Miles

The main argument in favor of using emissions at 4,000 miles is that there are more, and consequently more statistically valid, test data

available at low mileages than at high mileages. However, this gives an advantage to a car such as Car C in the example, which may have low emissions at low mileage but has a high rate of deterioration. In this instance, the consumer of Car D would pay a higher charge relative to the consumer of Car C when, in reality, Car C contributes at least as much pollution as Car D.

b. Total Emissions Between 4,000 and 50,000 Miles

Total emissions between 4,000 and 50,000 miles would be the preferred method if the true life of an automobile were 50,000 miles. Since this is not the case, this basis loses its clear theoretical advantage.

c. Emissions at 50,000 Miles

The emissions level at 50,000 miles is currently used as the basis for certifying automobiles. One drawback of using this measure is the uncertainty in the test results due to the small number of test vehicles that can be practically run to this mileage. The lack of a good statistical sample becomes more important when the test is used to establish actual emission levels than when it is used as a measure in a pass-fail test.

Both the total emissions to 50,000 miles basis and the emission level at 50,000 miles suffer from this lack of statistical sampling. Since emission controls can be expected to continue deteriorating as the car is used past 50,000 miles, the emission rate at 50,000 miles is probably more indicative of a vehicles's total lifetime emissions than is the total emissions measured just to 50,000 miles.

2. Conclusion:

The emissions level at 50,000 miles is the best compromise measurement in light of the practical limitations imposed by the testing procdures.

G. SHOULD THE EMISSIONS LEVEL FROM EACH AUTOMOBILE OR THE AVERAGE EMISSION LEVEL OF A MANUFACTURER'S FLEET BE THE BASIS OF THE CHARGE?

Whatever type of NOx charge is imposed, the amount of the charge to be paid can be computed in two ways:

- Determine the emissions level of each car and use this value to compute the charge for each car from the charge schedule;
- Determine the sales weighted average emissions for a manufacturer and then compute the charge from the charge schedule, using the average emission value.

For some types of charge schedules (i.e., a linear sliding scale with credits) the total charge a manufacturer pays is the same for the two bases (Figure VI-9) while for other types of schedules the total charge paid can be quite different, depending on the base used (Figure VI-10).

FIGURE VI-9: FOR THIS TYPE OF CHARGE SCHEDULE THE SAME TOTAL CHARGE IS OWED IRRESPECTIVE OF WHETHER IT IS APPLIED ON AN INDIVIDUAL VEHICLE OR SALES WEIGHTED AVERAGE BASIS

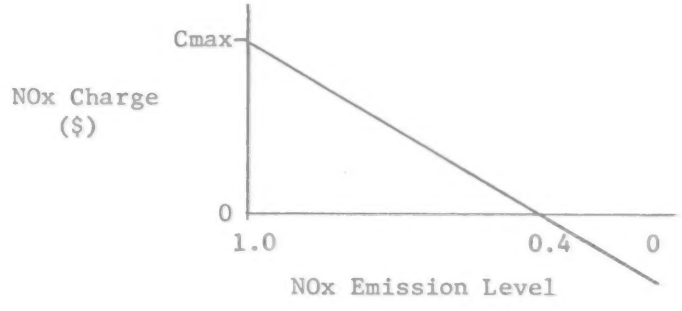
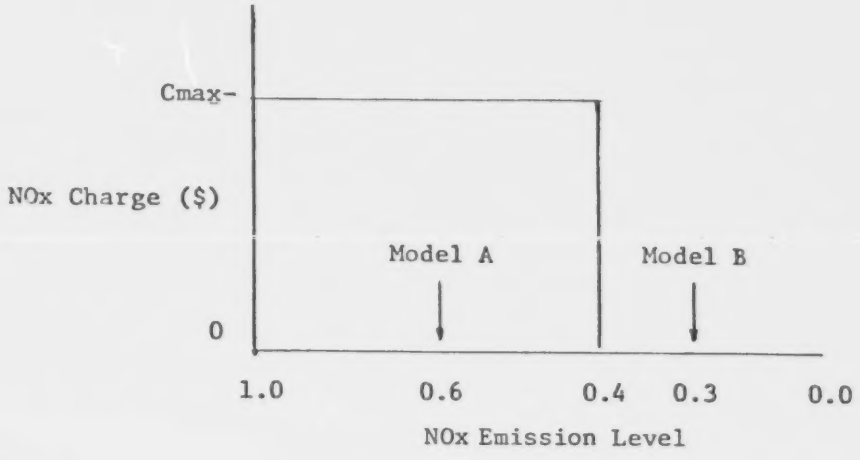


FIGURE VI-10: TOTAL CHARGE CAN DIFFER FOR ON-OFF OR STEPPED CHARGE DEPENDING ON WHETHER AN INDIVIDUAL VEHICLE OR SALES WEIGHTED AVERAGE BASIS IS USED



Total Sales = S
Sales Model A = ½S
Sales Model B = ½S
Cmax = charge rate

Sales weighted average emission = $(\frac{1}{2} \times 0.6) + (\frac{1}{2} \times 0.3) = 0.45$ NOx

Total Charge - Sale Weighted Average Basis

Since the sales weighted average emissions, 0.45, are greater than 0.4 a charge of Cmax must be paid for each vehicle sold. The total charge is the number of vehicles sold (S) multiplied by the charge rate (Cmax) or

- Total Charge (Sale Weighted Average Basis) = T x S

Total Charge (Individual Vehicle Basis)

The emissions of model B are less than 0.4 and thus no charge is owed on any sales of model B vehicles. The emissions of model A are greater than 0.4 and thus a charge of Cmax is owed for each model A vehicle sold (Sales of Model A = ½S).

- Total Charge (Individual Vehicle Basis) = ½S x Cmax

One argument for using a sales weighted average is that variations in the testing procedure may tend to average out, giving a more equitable result; however, this averaging will also occur--although perhaps to a lesser extent--when the different models are charged on the basis of their particular emission levels.

Conclusion

Either a vehicle-by-vehicle basis or a sales weighted average emission basis is reasonable. The choice will depend on the type of schedule chosen and the accuracy of emission measurements.

H. SHOULD THE EMISSIONS OF ONE CAR RELATIVE TO THE EMISSIONS OF OTHER CARS DETERMINE THE CHARGE?

An issue related to whether some average emissions rate for each manufacturer should be the base for the NOx charge is whether (1) an absolute charge schedule should be set up, or (2) a schedule with rates based on the emissions of one automobile relative to all other new automobiles should be used. To establish such a relative charge program, the general form of the schedule would be established then adjusted according to the actual sales weighted emissions for each model type. For example, one of the simplest types of a relative type charge would be a simple on-off charge with the automobiles in the upper half of the emissions distribution paying the full charge and those in the lower half paying either no charge or getting rebates equal to the amount of charge paid by the "upper half." This type of charge would require sales data to establish the sales weighted distribution and, thus, would require sales estimates at the start of the model year, which would be adjusted at the end of the year. Manufacturers would be uncertain as to how much charge they would have to pay until the end of the year. A charge based just on the distribution of emissions by model would not need sales data, but also would be unrealistic. The number of different models offered for sale should in no way affect the NOx charge.

The idea of a relative type of charge with manufacturers competing against each other to achieve lower NOx emissions is appealing. But it is not possible to predict manufacturers' responses nor to estimate

in advance what NOx levels would be achieved. To achieve real progress in NOx emissions, the government will have to establish a definite charge schedule based on definite emissions levels. We will not include any relative type of charge schedule in the alternative strategies presented.

Conclusion: Relative charge is impractical.

I. SHOULD SOME AUTOMOBILES BE EXEMPTED FROM THE CHARGE PROGRAM?

The question here is whether all automobiles should be subject to the same charge schedule. Different sized automobiles and/or automobiles with differing types of engines could be made subject to different charge schedules. However, since legislation and regulations to date have made no distinction between large and small automobiles, there is no compelling reason to do so here. This is especially true when a charge as opposed to a regulatory standard is being considered, since a prohibition on producing noncomplying automobiles is not considered.

The question of different charge schedules for different engine types is more complex. The Clean Air Act as amended in 1977 specifically makes provisions for the possibility of allowing a temporary relaxation of NOx standards for (1) innovative engine designs that may in the future provide improved fuel economy and reduced emission levels, and (2) diesel engines if it is determined that diesels will also provide fuel savings.

As stated above, these are both temporary exemptions, which permit production to continue while the technologies are being developed to bring the vehicles into compliance with the Act. The NOx charge under consideration would not prohibit the sale of any automobile, but would increase the cost of the automobile. Promising technologies could still be marketed at increased cost.

Once developed, a low NOx/fuel efficient automobile would have an added advantage over the competition, due to paying a low NOx charge. In

the case of automobiles that could not provide enhanced fuel economy and low NOx emissions, the consumer would still have the choice of buying the fuel-efficient automobile and paying the NOx charge.

Conclusion: No definite recommendation.

J. LEVEL OF CHARGES

The level of the charge we are considering, at least at the initiation of the NOx charge program, will reflect the costs of emissions control equipment.

Conclusion: Insufficient information to recommend a definite level.

K. COLLECTION AND USE OF THE CHARGE REVENUES

To avoid administrative problems, the charge should probably be assessed either when the car is sold to the dealer or when it is sold to the consumer. Payment could be made periodically by the manufacturer. Assessment based on sales to the consumer would result in lower charge payments since more cars are produced than are sold as new automobiles each year.

The main issue involved in the use of the revenues is whether the government should keep the revenues or disburse them as rebates to manufacturers or purchasers of low NOx emitting automobiles. This question was discussed above, where cash rebates were ruled out. Once this decision is made, the choice is between contributing any receipts to the General Fund or ear-marking the funds for some special use, such as paying the costs of administering the NOx program. Such ear-marking could be included, but there appears to be no compelling reason for not simply turning over any charges collected to the General Fund.

Conclusion: Revenues should be collected at time of sale and periodically turned over to the General Fund.

L. SUMMARY OF "CONCLUSIONS"

The following is a list of any "conclusions" reached with respect to the variables:

A. TYPE OF CHARGE SCHEDULE - Sliding scale, on-off and stepped are all reasonable. Because of measurement accuracy and the limited range between 1.0 and 0.4, a sliding scale and stepped charge (with more than one or two steps) are likely to be virtually synonymous.

B. REBATES AND CREDITS - Rebates should not be allowed; intra-credits are a reasonable option.

C. PHASE-IN CHARGE? The charge may be phased-in as long as the initial level of the charge is set high enough to elicit some real response.

D. WHEN SHOULD THE CHARGE BE IMPOSED? - Sufficient lead time should be included to allow manufacturers time to introduce equipment changes.

HOW LONG SHOULD THE CHARGE LAST? - The charge should last until the desired level is achieved; then this level may be required by regulatory standard.

E. TESTING PROGRAM - No single recommendation made, though certification is likely to be the most practical alternative.

F. EMISSION MEASUREMENT - Emissions at 50,000 accumulated miles should be used.

G. BASE CHARGE ON EMISSIONS OF EACH VEHICLE, OR MANUFACTURERS' SALES WEIGHTED AVERAGE? - Either method can be used.

H. BASE CHARGE ON THE EMISSIONS OF ONE VEHICLE RELATIVE TO THE EMISSIONS OF OTHER VEHICLES? - Relative basis is impractical.

I. EXEMPTIONS FOR SOME TYPES OF VEHICLES? - No determination made.

J. LEVEL OF CHARGE - Level should at least equal the costs of controlling emissions.

K. COLLECTION AND USE OF REVENUES - Charges are collected from manufacturers at time of sale and periodically turned over to the General Fund.

VII. UNKNOWNS IN DEVELOPING A CHARGE PROGRAM

In this chapter we review some of the findings of previous chapters which have a major impact on our ability to design and evaluate any NOx charge system. We place special emphasis on pointing out areas where there is a lack of important information, and on discussing what effect this lack of information has on the feasibility of proposing a NOx charge.

A. THE EFFECT OF A LACK OF INFORMATION ON EMISSION CONTROL TECHNOLOGIES ON THE DESIGN AND EVALUATION OF A NOx CHARGE SYSTEM

Detailed estimates of the differential cost of reducing NOx emissions from 1.0 to 0.4 are needed to estimate the impacts, both environmental and economic, of a charge program. As we pointed out in our discussion of emission control technologies in Chapter III, we do not have good estimates of these costs. We do have a range of possible costs but no good estimate of the sales weighted distribution of the future costs of control equipment is available.

1. Information on Control Technologies is Difficult to Obtain

The major reason for the difficulty in obtaining good cost estimates is that the state of the art of emission controls and even the design of the entire automobile is in a state of flux. For example, some form of exhaust gas treatment, such as a catalytic convertor, is utilized on most current model automobiles for control of emissions. In the future it may be possible to achieve the major part of emission control by modifying the basic engine design or utilizing some improved design fuel injection system so the level of pollutants leaving the engine itself are substantially reduced. These and other new technologies are now under development and/or undergoing evaluation so it is difficult at this point to predict which technology or combination of technologies will prove to be the best suited

to mass produced automobiles. In reality, the answer may well be a variety of technologies which are appropriate to the needs of the various models and classes of automobiles that will be offered in the market place.

Since emission control technologies and the automobiles themselves are changing over time, the costs (we are considering costs in constant dollar terms) associated with emission control will also change over time. As technology advances the real costs in terms of initial cost, drivability impairment, and fuel economy penalties of achieving any given level of emission should decrease. Thus the appropriate level of a NOx charge needed to achieve a certain level of emission reduction and the resultant impacts of that charge will differ depending on the year of imposition of the charge. Besides the change in cost due to changes in technology, there is also a difference in cost due just to the time available to the manufacturer to engineer and implement a changeover in production facilities.

2. Detailed Information on Emission Control Technologies is Needed

The major difficulty caused by a lack of good cost estimates arises in deciding on what level to set the charge at and in evaluating the consequences of the charge. The assumption we have made about the behavior of manufacturers essentially is that the manufacturer's reaction to a charge will be to choose the least cost option. If the charge is greater than the cost of installing control equipment, the control equipment will be installed. Even using this simple assumption one would prefer to obtain costs on a sales weighted basis, not just average costs, to be able to estimate more precisely the consequences of any level of charge. For example, if the average cost of controls is estimated to be $100/car one might assume that a $120 charge would induce installation of control equipment on all cars. However, if one knew the $100 average cost actually reflected a $50 cost for one half the cars and $150 cost for the other half, one would have arrived at the conclusion that a $120 charge would induce installation of controls on only one half the vehicles. One also needs

an estimate of how costs and benefits will vary over time, in order to compare the economic impacts of different charge systems on different manufacturers.

In preparing this report we have had to work with information available to the public. EPA receives current information from manufacturers on the progress they are making with emission control technologies and the plans they have for the future. This information is quite specific and thus is proprietary and not released until it is no longer of competitive value. Although most of this information probably relates to the current 1981 standard of 1.0 NOx, it is possible that there is sufficient information concerning lower NOx levels to permit the development of the type of information that would be useful in developing and evaluating the type of NOx charge under consideration in this report.

B. EMISSIONS MEASUREMENT UNKNOWNS AND THE DESIGN OF A NOx CHARGE

In this section we discuss in some depth two aspects of emission testing which have an impact on a NOx charge program:

- the accuracy of emissions measurement
- the relationship of presale test results to actual in-use emissions.

1. The Accuracy of Emissions Measurement

For a NOx charge to be defensible, the charge and the testing program which supports the charge should be formulated to give a reasonable assurance that charges reflect real emission levels. For example, a charge levied on the basis of one emission test when it is known that there are statistical variations caused by variations in the testing procedure, variation due to the vehicle itself, and variation between vehicles could result in different charges being

levied on different model automobiles that, in actuality, have the same level of emissions. The obvious way to avoid such problems is to design the charge, including the testing program, in such a way that the uncertainties related to single tests are removed by some type of averaging. There are many types of averaging that can be employed, ranging from establishing the emission level of a single model by multiple testing of that model, to basing the NOx charge on the average emissions of a manufacturer's entire yearly production by averaging the results of single tests on each individual model.

In order to properly design a NOx charge system with a compatible testing program, the magnitude of test measurement variability must be established. As we pointed out in Chapter IV, a thorough quantitative estimate of these values is not currently available. Thus, we cannot determine the extent of testing that would be needed to achieve a certain level of accuracy either of the emissions of a single model or of the average emissions of various groupings of different model vehicles.

2. The Relationship of Presale Tests to In-Use Emissions

In this section, we present the arguments for and against the necessity of explicitly considering the relationship of presale tests to in-use emissions in developing a NOx charge. The presentation of the "pro" position serves as a vehicle for bringing out the significant issues. At the end of the section, we present three possible approaches to dealing with the issues raised.

a. Argument in Favor of Explicitly Considering the Relationship of Presale Tests to In-Use Emissions

To be reasonable, an emissions charge should be based on some measure

which reflects the emissions of vehicles actually in use. Thus, before a charge is introduced, based on some pre point-of-sale emissions testing program, it should be demonstrated that this testing program will reflect the emissions of in-use vehicles. This is not to say that the emission levels determined in the testing program must be exactly equal to those found for in-use vehicles, but, rather, that the testing program results should at least correctly determine the relative in-use emissions of various vehicles. The charge system should be designed so that the difference in charges levied on various vehicles bears a direct relation to the actual in-use difference in the emissions of the vehicles.

For example, situations must be avoided where: 1) In the testing program two models are shown to have the same emission levels and are assessed the same charge, but the actual in-use emissions of the two models differ substantially; or 2) In the testing program, two models are shown to have different emission levels and are assessed different charges, but the in-use emissions of the two models are substantially the same. Other examples can easily be concocted where the charges could be said to be "unfairly" assessed in that, while they would reflect values found in a testing program, they would not be based on a quantification of the problem the charge was supposed to address--air pollution (NOx) caused by automobiles.

In the following paragraphs, we discuss the relationship of in-use emission levels to presale testing results obtained from programs such as the current EPA certification and SEA programs. For the moment we ignore most of the variabilities of emissions testing and concentrate on whether the vehicles tested fairly represent the vehicles which are purchased and driven by consumers.

i. Certification Test Results vs. In-Use Emissions

The current certification program tests prototype vehicles to determine if the basic design is adequate to meet emission standards. This is a reasonable first step in assuring that actual production models will meet the emissions standards. However, unless it can be demonstrated that the emission levels of these prototype vehicles accurately reflect the emission levels of production vehicles, it is inappropriate to base a NOx charge solely on the numerical values obtained in a certification type testing program. A good indication that the emission levels measured in the certification program are not directly applicable to in-use emissions can be obtained from simply looking at the current regulations for production line testing under SEA, which provide for a 40% Acceptable Quality Level (40% AQL). An SEA audit can be passed even though up to 40% of the emission measurements for each of the three pollutants (HC, CO, and NOx) are above the regulatory standard. On the other hand, the emission levels reported in conjunction with a vehicle being certified are the result of a single test where all three pollutants are below their respective regulatory standards. The 40% AQL was instituted in recognition of the fact that there are variations in mass-produced vehicles. Thus, on a vehicle-by-vehicle basis, the SEA and certification results are not necessarily expected to be the same. This does not answer the question of whether the mean emission levels of mass-produced vehicles actually equal the emissions of their corresponding certification vehicles.

ii. Production Line Test Results vs. In-Use Emissions

After a model has been certified, it goes into production where the SEA program is used to check the emissions of some production models. Only a limited number of models are tested, with most of the enforcement power of SEA being derived from the potential threat of being

selected for an audit. (i.e., Since a manufacturer does not know in advance the model or plant that will be selected for an audit, he must operate on the assumption that all his vehicles may be audited.) The current SEA program can be judged to be inadequate as the sole basis for assessing NOx charges, due to the small number of models actually tested. In addition, under the current program, the Deterioration Factor (DF) used in SEA is taken from the certification test results for the engine family emission control system combination to which the model tested under SEA belongs. Another difficulty in using the emission levels determined under SEA regulations is that there is no prescribed mileage, other than a maximum limit of 4,000 miles, at which the test must be conducted, and there is no prescribed method of accumulating the mileage. Of course, these procedures could be standardized if an assembly line testing program were instituted with a NOx charge.

Besides these difficulties with using the SEA program testing results, there is the more general question of whether any form of assembly line testing is a reasonable basis for a NOx charge. For the moment, still leaving aside the question of test variability and ignoring the attendant issues of how many tests would have to be performed, the question arises as to how closely the results of production line testing will be correlated with the emissions of in-use vehicles. Certainly the low mileage (4,000 miles) results should be equivalent. The major question arises when considering the rate at which the vehicle's emissions deteriorate in use as opposed to the rate which is measured in a controlled testing program.

It is generally the case that the rate of deterioration of the emissions of in-use vehicles is more rapid than the rate of deterioration measured in certification tests.[21] This is a result of many factors, such as: 1) Quality differences between certification vehicles and production vehicles, insufficient and/or improper maintenance, and actual tampering with emission control systems.[12]

This being the case, it may be inappropriate to use controlled tests to establish the deterioration rate to be used in determining the emission levels for applying a NOx charge. The primary goal of any automobile emission program is to induce manufacturers to produce vehicles which have low emissions throughout their actual use. If a controlled testing procedure is used to determine the rate of emissions deterioration, and thus the amount of the NOx charge, the impetus for the manufacturer to produce vehicles which perform well with regards to emissions in actual use, as opposed to just during a certification test, is removed. It might be possible to restore the impetus if the point of sale NOx charge were followed up by some in-use charge applied to the manufacturer or consumer, but, as we stated at the outset, we are not considering in-use testing in this report.

Even if it was decided to use a deterioration rate determined in a controlled test, the question remains as to whether the DF determined in the certification process would be adequate or whether a DF determined by testing production vehicles would have to be used. Using production vehicles would probably give the most representative results but would also probably be impractical due to the high cost and the length of time needed to complete the test.

b. Argument Against Explicitly Considering the Relationship of Pre-Sale Tests to In-Use Emissions

The argument against explicitly considering the relationship of pre-sale tests to in-use emissions when developing a NOx charge program can be succinctly stated:

The goal of the NOx charge is to induce manufacturers to improve the NOx control capability of their automobiles. In order to lower

the emissions measured in a presale test the NOx control capability of the vehicles must be improved. Thus a NOx charge program based on a pre-sale emission test, such as a certification test, is sufficient to achieve the goal. Any problems with in-use emissions should be left to another program, such as an inspection/maintenance program.

c. Possible Approaches to Dealing with the Question of the Relationship of Pre-Sale Tests to In-Use Emissions

While admitting that the degree of correspondence between certification type tests and production line tests with actual in-use emissions is unknown, there are still several approaches that can be taken with respect to a NOx charge based on pre-sale emission tests. Three approaches are suggested below.

i. Study the Relationship Further Before Instituting NOx Charge

One approach would be to empirically determine the strength of the correlation between certification/production line test results and in-use emissions. If a strong correlation were found, it could further be determined if the correlation was valid on a model-by-model basis or only on some average basis. The results of this study could be used to decide if a NOx charge based on pre-sale test results seemed reasonable. The results could also be used to aid in deciding on the general structure of the NOx charge and on the method of determining the emissions on which the charge would be based.

ii. Include In-Use Program With NOx Charge Program

Another approach would be to go ahead with a NOx charge based on pre-sale testing, and follow up on this charge with some type of in-use program which would penalize manufacturers whose vehicles' in-use

emissions were excessive. This penalty could be in the form of an additional charge owed, an adjustment to the charges owed by the manufacturer on his current production, or some corrective maintenance performed on the in-use vehicles at the manufacturer's expense.

iii. Ignore In-use Issue When Establishing NOx Charge Program

A third approach would be to simply go ahead with a NOx charge based on a pre-sale testing program, such as some version of the current certification program, without including any special examination of in-use emissions. The assumption would be that, although there might not be a one to one correspondence for every model, in general, as the emissions measured in certification type tests were reduced, the emissions of in-use vehicles would also be reduced. There might be some inequities under such a system (e.g., the relative emissions on which the NOx charge was based) but the NOx charge would still accomplish its overall goal of bringing about a reduction in NOx emissions.

The observations made in the above discussion are left to be considered in the final policy decision on the merits of a NOx charge and also in deciding whether some complementary in-use program should be instituted if a NOx charge based on pre-sale testing is implemented. In the next chapter we return to the more limited task of designing a NOx charge which is based only on pre-sale testing.

VIII. PROPOSALS OF SPECIFIC NOx CHARGE PROGRAMS

In this Chapter we present several NOx charge systems. As we have emphasized throughout this report, much of the quantitative information needed to make an evaluation of the consequences of various charge systems is not available. However, in order to illustrate how the various charge systems might work, we have made some assumptions regarding the costs of emission controls and the response of manufacturers to a NOx charge.

A. ASSUMED COSTS OF CONTROLLING EMISSIONS

In Chapter III we presented a recent estimate of the total costs for an "average" vehicle of controlling emissions to two NOx levels (1.0 and 0.4) while still achieving the statutory 1981 HC and CO levels of .41 and 3.4 respectively. These cost ranges in 1978 dollars are:

Emission Level	Range of Control Costs (1978 dollars)
.41/3.4/1.0	$194 to $285
.41/3.4/0.4	$236 to $377

These cost ranges overlap due to the uncertainties involved and due to the different types of equipment which may be used to control the emissions on different types of vehicles. Taking $0 as the minimum, the additional cost of reducing NOx emissions from 1.0 to 0.4 falls in a range of $0 to $183. We have selected the approximate mid point of this range, $90, and the approximate maximum of the range, $180, to use as examples in illustrating how various NOx charges might work. We emphasize that this selection is arbitrary, and no particular significance should be attached to the absolute

numerical values obtained in any of the calculations made using the $90 and $180 figures. Any calculations made are made only for illustrative purposes.

We would also like to emphasize that the $90 figure is not selected to represent the most probable cost of emission control or the average cost of emissions control. As will become obvious in the examples that follow, an average cost of control equipment is not of much use in estimating the effects of a NOx charge. One really needs the distribution of costs to control various vehicles. In this regard we could have selected a multitude of control costs, assigned weights as to the number of vehicles to which each cost would apply and made detailed calculations of the probable effects of various types of NOx charges. Since, with the information available, this would all have to be done on an arbitrary basis the results would be meaningless and might tend to confuse the issue by giving the incorrect impression that a detailed quantitative evaluation of the impact of a NOx charge can be made with currently available information. We have chosen instead to illustrate our examples with two values for the cost of controlling emissions to 0.4 and include a discussion of the possible effects a range of emission control costs would have.

Unless otherwise noted, in the remainder of this report, when the "costs of emission control" are referred to, this should be taken to mean the differential cost to reduce emissions from 1.0 NOx to whatever level is specified. For example, the values $90 and $180 in the preceding paragraph will be referred to as the cost of controlling emission to 0.4 and the cost of controlling emissions to 1.0 NOx will be taken as $0.

Even if the total costs of controlling emissions to 0.4 NOx

are known, more detailed information as to the various costs of controlling emissions to intermediate levels between 1.0 and 0.4 are needed to estimate what the response to a NOx charge may be. In order to illustrate an example, we make some assumptions about the costs of controls at intermediate levels, while maintaining the assumption of a $90 or $180 cost at 0.4 NOx. The three cost schedules we assume for the two cases ($90 and $180) are given in the following table.

TABLE VIII.1. ASSUMED COSTS OF EMISSION CONTROLS

$90 at 0.4 NOx

NOx Emission Level	Cost of Controls		
gm/mile	Cost A	Cost B	Cost C
1.0	0	0	0
0.8	30	15	45
0.6	60	45	75
0.4	90	90	90

$180 at 0.4 NOx

NOx Emission Level	Cost of Controls		
gm/mile	Cost A	Cost B	Cost C
1.0	0	0	0
0.8	60	30	90
0.6	120	90	150
0.4	180	180	180

These cost schedules represent only three of the many possible ways the costs of controlling emission between 1.0 and 0.4 could vary. However, they do indicate three basic ways the costs could vary: The "A" costs vary linearly with the emission level; the "B" costs show the costs per unit of emission reduction increasing as the emission level is decreased; and the "C" costs show the cost per unit of reduction decreasing as the emission level is decreased. At first glance the C costs schedule may seem unlikely, however, it is perfectly plausible, if one considers the fact that in order to decrease emissions at any given level of emissions a new type of control equipment may have to be introduced. This may cause a relatively large "jump" in emission control costs, and, if a change were required at a level near 1.0 NOx as opposed to near 0.4 NOx, a schedule such as schedule C might well apply.

The costs referred to thus far have all represented costs of the control equipment itself. Costs of any increased maintenance, decrease in fuel economy, and/or adverse effects on drivability due to decreasing emission from 1.0 to 0.4 NOx have not been considered. Since we have no good information on these factors (it has been estimated that it is possible to achieve 0.4 NOx with no adverse "side" effects) we make the assumption that there will be no effect on maintenance costs, fuel economy and drivability.

B. ASSUMED RESPONSE OF MANUFACTURER TO A NOx CHARGE.

Possible responses of manufacturers to a NOx charge were discussed in Chapter V. For the purposes of the examples in the following section of the present Chapter, we make the assumption that the manufacturers will choose the least cost option. In other words, the manufacturers will choose to control the emissions from his vehicles to a point where the sum of the cost of the control equipment plus any NOx charge owed is a minimum.

C. CHARACTERISTICS COMMON TO ALL PROPOSED NOx CHARGE PROGRAMS

Although we present several different NOx charge systems, each of the systems has some identical characteristics. Instead of repeating these characteristics in the description of each proposed charge system we summarize the common facets:

- The sale of automobiles with emissions above .41/3.4/1.0 is prohibited.
- Charge lasts at least until desired level is achieved by all.
- Revenues are returned to general fund except perhaps for monies needed to support the charge program.
- Charge is collected from the manufacturers at time of sale.
- Charge is based on emission levels at 50,000 miles.
- The question of exemptions for fuel efficient technologies is left open.

D. PROGRAM A - SLIDING SCALE CHARGE

This section describes one of the proposed NOx charge programs. This program will be identified as "Program A" and is summarized as follows:

Program A is a sliding scale NOx charge based on emission levels determined in the EPA certification program. (Some changes, which are described below, will have to be made in the current certification program.)

The specifics of Program A are as follows.

1. Type of Charge

- Linear sliding scale charge with the maximum charge (Cmax) at 1.0 NOx decreasing linearly to zero charge at 0.4 NOx and extending linearly in a region of negative charge to 0.0 NOx (see Figure VIII-1).

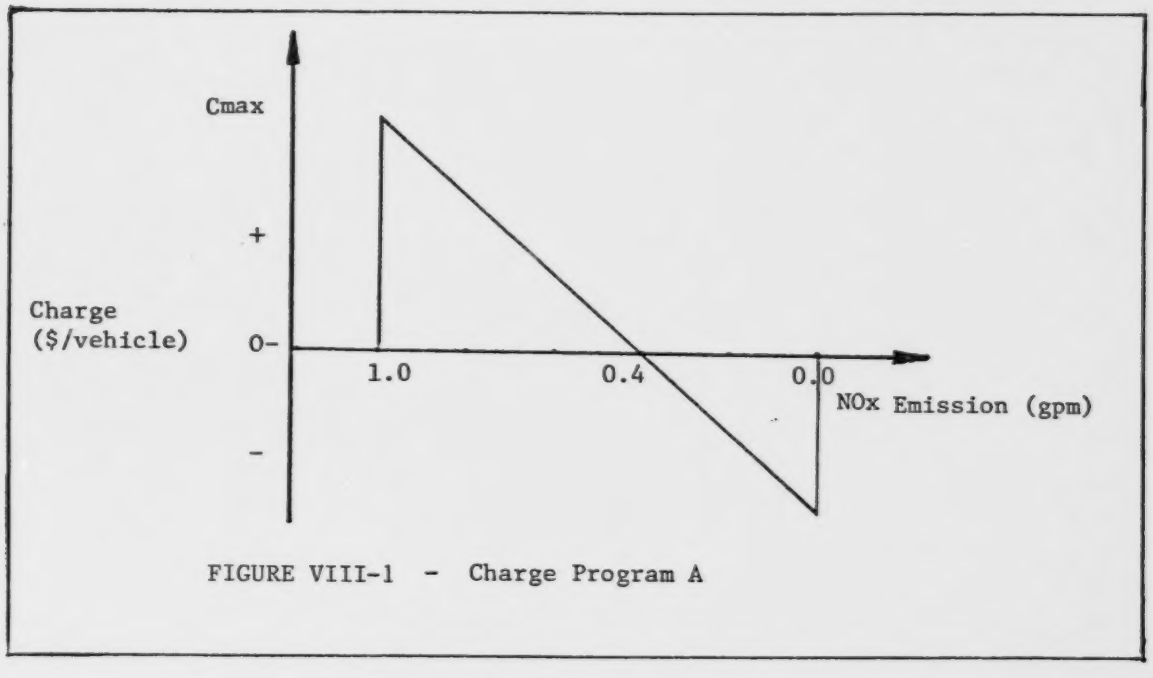


FIGURE VIII-1 - Charge Program A

Analytically the Program A charge is given by:

$$\text{NOx Charge} = \frac{5}{3} \bullet (\text{Cmax}) \bullet (\text{NOx}) - \frac{2}{3} \bullet (\text{Cmax})$$

For $1 \geq \text{NOx} \geq 0$

Where:

NOx Charge = Charge owed per vehicle

NOx = NOx emissions in grams per mile (gpm)

Cmax = NOx Charge at NOx = 1.0

- Negative charges can be used to offset positive charges owed.
- Once the value Cmax is set, the level of the charge for all values of NOx is determined.

2. Method of Assessing Charge

Since the charge is to be paid by the manufacturer, there are two equivalent methods of assessing a sliding scale charge. (The equivalence of these two methods in the case of a sliding side charge was demonstrated in Chapter VI.):

- For an individual manufacturer either 1) Determine the charge owed on each car individually from the charge schedule then sum the charges over all cars sold; or, 2) Determine the sales weighted average emissions; Determine the charge that would be owed for a vehicle with emissions equal to the sales weighted average emissions from the charge schedule; Multiply this value by the total number of cars sold.

Thus, although the charge can be computed on a car by car basis, in this case the total charge owed is a function of each manufacturer's sales weighted average emissions.

3. Method of Determining Emissions

The emission levels measured in the certification testing program will be used as a basis for assessing the charge. The 50,000 mile levels will be used (i.e., the levels determined from the emission data vehicles (4,000 miles) multiplied by the appropriate deterioration factor).

Two changes in the current certification program may have to be made:

- EPA is experimenting with an abbreviated certification program which increasingly relies on test results supplied by the manufacturer as opposed to test results obtained in the EPA laboratory. To ensure a consistent determination of the emission levels to be used as a basis for a NOx charge, a reconciliation of this trend with the need for a charge program must be made.

- Since all model configurations are not specifically tested in the certification program the number of configurations tested may have to be increased. How much of an increase would be required is not clear. It may be possible through an engineering evaluation to assign emission levels to untested vehicle configurations on the basis of their similarity to the vehicle configuration that was tested. In addition, since the charge program being considered here (Program A) assesses a manufacturer's total charges on a sales weighted average basis, and since the vehicle configurations expected to have high sales volumes are tested in the certification program, the problem of untested vehicle configurations may not be a significant concern.

4. Level of Charge

The only value that must be set to determine the charge at all emissions levels is the charge (Cmax) for emissions at a level of 1.0 NOx. Since we have no good estimate of the distribution of costs of controlling the NOx emissions of various vehicles to 0.4 and to other levels between 1.0 and 0.4, we do not recommend a specific level of charge at this time. A value for Cmax could be arbitrarily recommended, but, without more cost of control information, the impact of imposing the charge cannot be reasonably estimated. As an alternative, we present illustrative examples using the cost of control assumptions discussed in a previous section of this Chapter.

5. Illustrative Example - Program A

Assuming different values of Cmax, total cost (cost of emission controls + amount of NOx charge owed) schedules were computed for the cost of control assumptions described earlier in this Chapter. The results of these computations are presented in Tables VIII-2A and VIII-2B. Table VIII-2A presents total costs computed using five values of Cmax ($60, $90, $120, $135 and $150) and the three cost schedules in which the cost of controlling emission to 0.4 NOx is $90. Table VIII-2B presents total costs calculated using five values of Cmax ($150, $180, $210, $240 and $270) and the three cost schedules in which the cost of controlling emissions to 0.4 NOx is $180.

The columns in Tables VIII-2A and VIII-2B contain the following values:

Column 1 - Level of NOx emissions.

Columns 2, 3, and 4 - Three assumed cost schedules (Cost A, B and C) for controlling NOx emissions to values between 1.0 and 0.4.

Column 5 - The amount of the NOx charge.

Columns 6, 7, and 8 - The total cost of emission control equipment plus the NOx charge owed at various NOx levels for each of the cost schedules. For example, column 7 is the sum of column 3 (the cost of emission controls under assumed cost schedule B) and column 5 (amount of NOx charge).

TABLE VIII-2A. TOTAL COSTS WITH VARIOUS VALUES OF Cmax

(Emission Control Costs = $90 at 0.4 NOx)

NOx Emission Level (gpm)	Cost of Emission Control Equipment ($)			NOx Charge ($)	Total Cost ($) (Equipment Cost + Charge)		
	Cost A	Cost B	Cost C		Cost A	Cost B	Cost C
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			Cmax = $60				
1.0	0	0	0	60	*60*[1]	60	*60*
0.8	30	15	45	40	70	*55*	85
0.6	60	45	75	20	80	65	95
0.4	90	90	90	0	90	90	90
			Cmax = $90				
1.0	0	0	0	90	*90*	90	*90*
0.8	30	15	45	60	*90*	*75*	105
0.6	60	45	75	30	*90*	*75*	105
0.4	90	90	90	0	*90*	90	*90*
			Cmax = $120				
1.0	0	0	0	120	120	120	120
0.8	30	15	45	80	110	95	125
0.6	60	45	75	40	100	*85*	115
0.4	90	90	90	0	*90*	90	*90*
			Cmax = $135				
1.0	0	0	0	135	135	135	135
0.8	30	15	45	90	120	105	135
0.6	60	45	75	45	105	*90*	120
0.4	90	90	90	0	*90*	*90*	*90*
			Cmax = $150				
1.0	0	0	0	150	150	150	150
0.8	30	15	45	100	130	115	145
0.6	60	45	75	50	110	95	125
0.4	90	90	90	0	*90*	*90*	*90*

1 - * * indicates minimum cost points

TABLE VIII-2B. TOTAL COSTS WITH VARIOUS VALUES OF Cmax

(Emission Control Costs = $180 at 0.4 NOx)

NOx Emission Level (gpm)	Cost of Emission Control Equipment ($)			NOx Charge ($)	Total Cost ($) (Equipment Cost + Charge)		
	Cost A	Cost B	Cost C		Cost A	Cost B	Cost C
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			Cmax = $150				
1.0	0	0	0	150	*150* [1]	150	*150*
0.8	60	30	90	100	160	*130*	190
0.6	120	90	150	50	170	140	200
0.4	180	180	180	0	180	180	180
			Cmax = $180				
1.0	0	0	0	180	*180*	180	*180*
0.8	60	30	90	120	*180*	*150*	210
0.6	120	90	150	60	*180*	*150*	210
0.4	180	180	180	0	*180*	180	*180*
			Cmax = $210				
1.0	0	0	0	210	210	210	210
0.8	60	30	90	140	200	170	230
0.6	120	90	150	70	190	*160*	220
0.4	180	180	180	0	*180*	180	*180*
			Cmax = $240				
1.0	0	0	0	240	240	240	240
0.8	60	30	90	160	220	190	250
0.6	120	90	150	80	200	*170*	230
0.4	180	180	180	0	*180*	180	*180*
			Cmax = $270				
1.0	0	0	0	270	270	270	270
0.8	60	30	90	180	240	210	270
0.6	120	90	150	90	210	*180*	240
0.4	180	180	180	0	*180*	*180*	*180*

1 - * * indicates minimum cost points

In columns 6, 7, and 8 the minimum total cost or costs for each cost schedule under each of the four charge schedules are indicated by asterisks (**). Using the assumption that a manufacturer will opt for the least cost situation, the level of emission control and the charge paid under each circumstance can be determined. In cases where there is more than one "minimum" cost, a reasonable assumption is that the manufacturer will follow the "easiest" path and install the minimum amount of control equipment to reach a minimum cost point.

As can be seen from examining Tables VIII-2A and VIII-2B, the expected response to any particular charge can be quite different depending on the specific manner in which costs vary as emission levels are reduced. It can also be noted that in some instances, such as in the examples under "cost B", the maximum charge, Cmax, must be significantly above the cost of controlling emission to 0.4 NOx in order to make 0.4 the minimum cost level. For example, under the cost B schedule where the cost of controlling emissions to 0.4 NOx is taken to be $90 (Table VIII-2A), the maximum charge, Cmax, must be at least $135 for the 0.4 NOx emission level to be the minimum cost level. For the case of the cost B schedule where the cost of controlling emissions to 0.4 NOx is taken to be $180 (Table VIII-2B), the maximum charge must be at least $270 for the 0.4 NOx emission level to be the minimum cost level.

E. PROGRAM B - ON-OFF CHARGE

This section describes the second proposed NOx charge program which is identified as "program B" and is summarized as follows:

Program B is an on-off type charge combined with a sliding scale charge for vehicles with emissions above a certain "zero charge" level. The charge is phased in by decreasing the zero charge level over time. The charge is assessed on the basis of the emissions of individual vehicles--not on the basis of a

manufacturer's sales weighted average emissions.

The specifics of the program are as follows.

1. Type of Charge

The program B charge is illustrated in Figure VIII-2

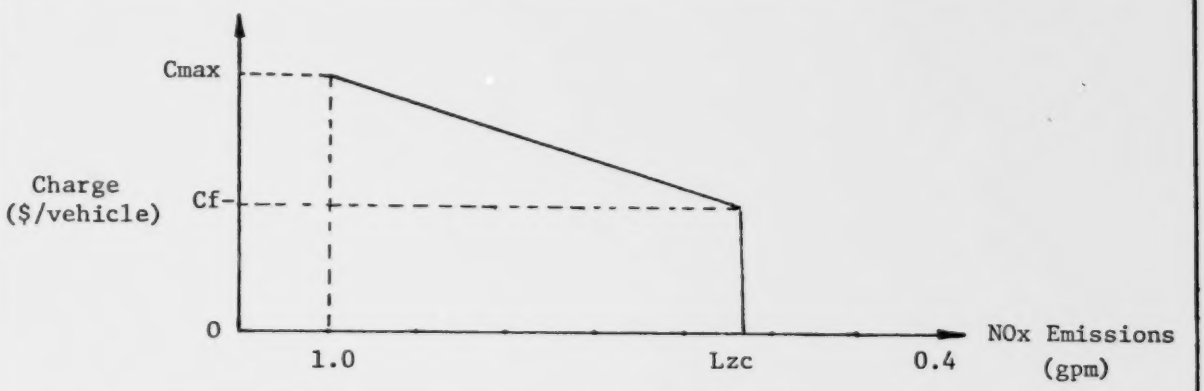


FIGURE VIII-2 - Charge Program B

The charge operates in the following manner:

- Zero charge will be assessed on vehicles with emissions at or below a certain NOx emission level, which we will call the "zero charge level" (Lzc).
- The charge is phased in by specifying the value of Lzc be set at 0.8, 0.6, and 0.4 in the first, third, and fifth year of the charge program. Thereafter Lzc remains at 0.4.
- Vehicles with emissions that exceed Lzc will be assessed a charge which is the sum of a constant fixed charge, Cf, plus a linear sliding scale charge, which varies with the emission level. The total charge assessed on a vehicle is given analytically by:

$$\text{NOx Charge} = Cf + (Cmax - Cf) \bullet \frac{NOx - Lzc}{1 - Lzc} \qquad 1 \geq NOx > Lzc$$

$$= 0 \qquad Lzc \geq NOx \geq 0$$

Where:

NOx = Level of NOx emissions in grams/mile

Cmax = Total Charge ($) assessed on a vehicle with NOx = 1.0

Cf = Fixed Charge (constant charge level for all vehicles with NOx $\geq$ Lzc)

Lzc = NOx level below which no charge is assessed ("zero charge level")

The charge schedule is completely specified when values are given to Cmax, Cf, and Lzc. Values of Cmax and Cf are discussed below in section 4 "Level of Charge". The value of Lzc has been left as a variable instead of being fixed at 0.4 since we propose that the charge be phased in by decreasing the value of Lzc over time. We propose values of Lzc of: 0.8 in years 1 and 2; 0.6 in years 3 and 4; and 0.4 thereafter. This is an arbitrary, although seemingly reasonable, selection of values which can and should be modified when more information on the capabilities and costs of control equipment are available. In addition, although program B is specified here as a phased in charge, it is equally possible to leave this provision out of the program and simply set Lzc permanently at 0.4 in the first year of the charge program.

a. Why Include a Sliding Charge with the Fixed Charge?

Program B includes a sliding scale charge along with a fixed charge, since if only a fixed charge is applied there is no inducement for a manufacturer to reduce emissions at all if he feels he cannot reduce them sufficiently to avoid the charge altogether. This is illustrated in the following example.

The charge we use as an example is a simple on-off charge which is phased-in in three steps. The charge is $100 if NOx emission levels are above the zero charge level (Lzc) and $0 if NOx emission levels are equal to or below Lzc. Lzc is assigned the following values:

Year 1 and 2	Lzc = 0.8
Year 3 and 4	Lzc = 0.6
Year 5 and thereafter	Lzc = 0.4

Using this charge schedule we make the same type of calculations of total costs (cost of control equipment plus amount of NOx charge) as were made in the examples pertaining to program A. The assumed costs of controls are costs A, B, and C given in Table VIII-1 and repeated in columns 2, 3 and 4 respectively of Table VIII-3. The remaining columns in Table VIII-3 give the following values: column 1 - NOx emission level; column 5 - amount of NOx charge; and columns 6, 7 and 8 the total costs under the charge schedule.

Table VIII-3 shows what may be an obvious yet nonetheless important result. In all cases the minimum cost point (marked by asterisks) is achieved by controlling emissions to the minimum extent possible, while still reaching a sufficiently low NOx level to avoid the charge However, if the charge is not avoided the least cost point is reached by installing no control equipment. The maximum cost point is achieved if sufficient control equipment is installed to just miss avoiding the charge. These observations are best exemplified by the costs in Table VIII-3 for "year 5 and thereafter". This case can also be viewed as an example of an on-off charge which is not phased in. For the particular numbers used in this example it is probable that, unless the manufacturer were certain his control equipment would be adequate to avoid the charge, the manufacturer might very well adopt the riskless approach of not installing any

TABLE VIII-3. EXAMPLE OF TOTAL COSTS UNDER AN ON-OFF CHARGE

(Emission Control Costs = $90 at 0.4 NOx)

NOx Emission Level (gpm)	Cost of Emission Control Equipment ($)			NOx Charge ($)	Total Cost ($) (Equipment Cost + Charge)		
	Cost A	Cost B	Cost C		Cost A	Cost B	Cost C
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			Year 1 and 2				
1.0	0	0	0	100	100	100	100
0.8	30	15	45	0	*30*[1]	*15*	*45*
0.6	60	45	75	0	60	45	75
0.4	90	90	90	0	90	90	90
			Year 3 and 4				
1.0	0	0	0	100	100	100	100
0.8	30	15	45	100	130	115	145
0.6	60	45	75	0	*60*	*45*	*75*
0.4	90	90	90	0	90	90	90
			Year 5 and Thereafter				
1.0	0	0	0	100	100	100	100
0.8	30	15	45	100	130	115	145
0.6	60	45	75	100	160	145	175
0.4	90	90	90	0	*90*	*90*	*90*

1 - * * indicates minimum cost points

additional control equipment beyond that necessary to meet 1.0 gpm. An on-off charge can actually work as a disincentive in cases where there is a question as to whether control equipment will prove adequate to reduce emissions below the zero charge level.

2. Method of Assessing Charge (Resumption of program B description)

The charge owed by each manufacturer is assessed on a vehicle by vehicle basis by:

1) Assigning emission levels to each vehicle
2) Determining the charge owed on each vehicle from the charge schedule
3) Summing the individual charges.

In general, a manufacturer's sales weighted average emissions are preferred as a basis for assessing a charge since the effects of any variabilities in emission measurements are minimized. However, in the case of program B a sales weighted average basis could lead to large differences in the total charges a manufacturer must pay as compared to a charge assessed on an individual vehicle basis.

As an illustration, at emission levels in the vicinity of the zero charge level, Lzc, the charge discontinuously jumps from zero to the value specified for Cf. If a manufacturer's sales weighted average emissions were used as the basis for the charge a very small shift in the average from slightly below to slightly above Lzc would mean a shift from owing no charge to owing Cf dollars for every car sold by the manufacturer in the model year. Since we are considering manufacturers who sell millions of units per year and Cf may well be of the order of $100 or $200, this would represent a huge charge for a very small change in emission levels. One can even imagine a scenario in which a manufacturer, near the end of a model year determines that his average emissions are slightly above Lzc,

and, realizing that he could reduce his total charges, induces sales of low NOx emitting cars to reduce his sales weighted average emissions below Lzc by drastically lowering prices to avoid the NOx charge.

When the emissions of individual vehicles are used as the basis, situations can also arise where a small difference in emissions leads to a large change in charges owed on that vehicle, but, due to the number of units involved, the overall impact is much less than in the case of a sales weighted average basis. These situations are unfortunate but cannot be avoided in a stepped charge program.

3. Methods of Determining Emissions

The emission levels measured in the certification testing program will be used as a basis for assessing the charge. Most appropriately, the 50,000 mile levels should be used (i.e., the levels determined from the emission data vehicles (4,000 miles) multiplied by the appropriate deterioration factor).

This is the same testing program used in program A. The same comments as to possible changes that might be needed in the certification program already made with respect to program A also apply here.

4. Level of Charge

There are two values, Cf, the fixed charge, and Cmax, the total charge at 1.0 NOx, that must be set to specify the complete charge schedule. (Values of Lzc, the zero charge emission level were specified earlier and will be repeated below.) As with the charge level in program A the data necessary to recommend a charge level were not publicly available. We follow basically the same procedure here as in our discussion of program A and instead of announcing the proper charge level defer instead to an illustrative example based on largely hypothetical costs. However, before

presenting the example we make some general comments regarding the establishment of Cf and Cmax.

The charge is to be phased-in in three steps by initially setting Lzc = 0.8 then reducing Lzc to 0.6 and finally to 0.4. In the first stage the charge will only be assessed on emission levels in a narrow range, 1.0 to 0.8. The sliding scale portion of the charge will not be included in the first stage but will be included in the second and third stages. The value of Cf will be the same in each stage while the value of Cmax will be increased in moving from one stage to the next. One possible, although arbitrary, relationship between the various values is shown below.

Year	Lzc	Cf	Cmax - Cf
1 and 2	0.8	K	0
3 and 4	0.6	K	2A
5 onward	0.4	K	3A

5. Illustrative Example of Program B.

Tables VIII-4A and B present examples of the total cost per vehicle (cost of emission control equipment plus amount of NOx charge) under several program B charge schedules. Table VIII-4A presents results for the case where the cost of controlling emissions to 0.4 is assumed to be $90 and Table VIII-4B presents results for the case where the cost of controlling emissions to 0.4 is assumed to be $180. The values of Cmax and Cf used to specify the charge are shown at the bottom of the appropriate tables. The general format of Tables VIII-4A and B is the same as in previous examples (i.e., column 1 - NOx emission level, columns 2, 3, and 4 - emission control costs, column 5 - amount of NOx charge, columns 6, 7, and 8 total costs under the various assumed emission control costs with the minimum cost points indicated by (* *)).

TABLE VIII-4A. PROGRAM B EXAMPLE - TOTAL COSTS PER VEHICLE

(Emission Control Costs = $90 at 0.4 NOx)

NOx Emission Level (gpm)	Cost of Emission Control Equipment ($)			NOx Charge ($)	Total Cost ($) (Equipment Cost + Charge)		
	Cost A	Cost B	Cost C		Cost A	Cost B	Cost C
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			Years 1 and 2				
1.0	0	0	0	45	45	45	*45*
0.8	30	15	45	0	*30*[1]	*15*	*45*
0.6	60	45	75	0	60	45	75
0.4	90	90	90	0	90	90	90
			Years 3 and 4				
1.0	0	0	0	105	105	105	105
0.8	30	15	45	75	105	90	120
0.6	60	45	75	0	*60*	*45*	*75*
0.4	90	90	90	0	90	90	90
			Year 5 Onward				
1.0	0	0	0	135	135	135	135
0.8	30	15	45	105	135	120	150
0.6	60	45	75	75	135	120	150
0.4	90	90	90	0	*90*	*90*	*90*

Values Used to Specify the Charge

Years	Lzc	Cf	Cmax	Cmax - Cf
1 and 2	0.8	45	45	0
3 and 4	0.6	45	105	60
5 onward	0.4	45	135	90

1 - * * indicates minimum cost points

TABLE VIII-4B. PROGRAM B EXAMPLE - TOTAL COSTS PER VEHICLE

(Emission Control Costs = $180 at 0.4 NOx)

NOx Emission Level (gpm)	Cost of Emission Control Equipment ($) Cost A	Cost B	Cost C	NOx Charge ($)	Total Cost ($) (Equipment Cost + Charge) Cost A	Cost B	Cost C
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			Years 1 and 2				
1.0	0	0	0	90	90	90	*90*[1]
0.8	60	30	90	0	*60*	*30*	*90*
0.6	120	90	150	0	120	90	150
0.4	180	180	180	0	180	180	180
			Years 3 and 4				
1.0	0	0	0	210	210	210	210
0.8	60	30	90	150	210	180	240
0.6	120	90	150	0	*120*	*90*	*150*
0.4	180	180	180	0	180	180	180
			Year 5 Onward				
1.0	0	0	0	270	270	270	270
0.8	60	30	90	210	270	240	300
0.6	120	90	150	150	270	240	300
0.4	180	180	180	0	*180*	*180*	*180*

Values Used to Specify the Charge

Years	Lzc	Cf	Cmax	Cmax - Cf
1 and 2	0.8	90	90	0
3 and 4	0.6	90	210	120
5 onward	0.4	90	280	180

1 - * * indicates minimum cost points

IX. CONCLUSION

Although a NOx charge is theoretically sound, there are several major uncertainties which, unless resolved, significantly detract from the feasibility of implementing such a charge. These uncertainties have impacts in two general areas: 1) Administrative feasibility and 2) Prediction of the impacts, both environmental and economic, of a charge program. We have discussed both these topics in the body of this report but briefly restate the issues below.

A. UNCERTAINTIES AFFECTING ADMINISTRATIVE FEASIBILITY

The major issue with respect to the administrative feasibility of a NOx charge involves the measurement of the NOx emission levels on which the charge is based. There are unanswered questions as to the accuracy and degree of variability of emission measurements on a single vehicle and also as to how representative the emissions of one test vehicle are of the emissions of other "identical" vehicles.

Another important question involves the number of models and various configurations of those models that will need to be tested under a NOx charge program. For example, if certification test results are used as a basis for the charge, the number of models and configurations tested may have to be increased depending on the specific requirements of the charge program. Any increase in testing or other change in current testing programs will influence whether or not a charge program is administratively feasible.

B. UNCERTAINTIES AFFECTING THE PREDICTION OF THE IMPACTS OF A NOx CHARGE

The question at issue here is simply, "If a certain NOx charge program is instituted, what will be the result?". There are two types of information that are of primary importance in answering this question: 1) Detailed

estimates of the costs of controlling NOx emissions to various levels and 2) Estimates of the likely responses of manufacturers to a NOx charge. These are closely related, although not identical issues.

1. Effects of Uncertainties in the Cost of Emission Controls

The first step in evaluating the impact on emissions of a NOx charge is to estimate schedules of costs vs emission levels which manufacturers face as a result of the charge. Using these estimates the financial incentives to reduce emissions can be estimated. To obtain an estimate of both the number of vehicles for which there will be a financial incentive to reduce emissions, and the magnitude of these incentives at various emission levels, detailed estimates of the cost of controlling NOx emissions to various levels for various vehicles are needed. An estimate of the average cost of controlling an "average" vehicle is not sufficient since controls are installed on specific vehicles not on average vehicles. Average costs can only be used to get a general idea of the range of charge levels which may be needed.

Since such detailed estimates of the cost of controlling emissions were not available, the extent of the financial incentives to reduce emissions under a charge program cannot be reliably estimated.

2. Effects of Uncertainties in Manufacturers' Responses to a Charge

An estimate of the responses of manufacturers to a NOx charge depends, in this study, on an assumption of economic rationality. The extent to which manufacturers might respond by absorbing all or part of the charge in an effort to affect buyers' short run purchasing habits is beyond the scope of this study.

Unless these issues regarding the cost of controlling emissions and the responses of manufacturers can be resolved, it is difficult to

estimate the reduction in NOx emissions that will result from any specific NOx charge program.

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